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ENVIRONMENTAL SURVEY OF AN INTERIM OCEAN DUMPSITE, MIDDLE ATLANTIC BIGHT, CRUISE REPORT - 1-5 MAY 1973

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Westinghouse Ocean Research Laboratory

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An oceanographic survey cruise was made to a proposed interim sludge dumping site on the continental shelf in the Middle Atlantic Bight in spring 1973. Observations were made of circulation patterns, sediment composition, bathymetry, water quality, heavy metals in sediments and biota, bacteriology, phytoplankton communities, zooplankton communities, vertebrates, and benthic invertebrates.

The site was found to be a normal mid-temperature shelf environment, with no significant stresses. Evidence of heavy metals enhancement of iron and copper in the epifauna at some stations warrants further investigation.

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ENVIRONMENTAL SURVEY OF AN INTERIM OCEAN DUMPSITE

Middle Atlantic Bight

Cruise Report — 1-5 May 1973

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ABSTRACT

An oceanographic survey cruise was made to a proposed interim sludge dumping site on the continental shelf in the Middle Atlantic Bight in spring 1973. Observations were made of circulation patterns, sediment composition, bathymetry, water quality, heavy metals in sediments and biota, bacteriology, phytoplankton communities, zooplankton communities, vertebrates, and benthic invertebrates.

The site was found to be a normal mid-temperature shelf environment, with no significant stresses. There was some evidence that material from a neighboring acid waste dumpsite may affect the site. Evidence of heavy metals enhancement of iron and copper in bottom fauna at some stations warrants further investigations.

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CONCLUSIONS

Bottom configurations in the interim dumpsite were found to be in accordance with published charts. No unexpected holes, trenches, or rises were found with detailed bathymetry.

Bottom substrate was primarily quartz sand, with a gradation from coarse to fine as a function of depth and effective wave energy. The sorting values of sediment were evaluated to determine sites on the bottom where waste deposition may accumulate. Subsequent interpretation indicated that these regions occupy topographic "lows" within the dumpsite.

Shipboard current measurements indicated a flow of the water column at approximately 0.25 knot in a direction between 192° and 248° true, under the regime of observation. Seabed drifters released during the cruise indicate a net southwestward movement of near-bottom waters to the coastline.

Hydrographic conditions indicated the partial establishment of the thermocline and halocline. These conditions would be important in the settling and distribution of dumped materials.

Measured water quality parameters indicated no abnormal concentrations of the compounds generally encountered in the marine environment. Ammonia determinations were not amenable to preservation for later analysis.

Phytoplankton and zooplankton populations were typical of a normal temperate shelf environment.

Vertebrates were observed by underwater television and by capture with an otter trawl. The demersal community examined appeared to be in sound physiological condition.

The benthic fauna was characteristic of a firm sand-shell-gravel community, dominated by sea stars, sand dollars and polychaetes. Suspension feeders and carnivores were extremely well represented. The sand bottom community was surprisingly diverse and abundant. Any significant changes — or more specifically reductions in populations of sand dollars, principal polychaetes and some of the more fleshy ectoprocts — would be indicative of degradation in bottom water quality. However, based on the benthic fauna, the site was unpolluted.

Coliform and fecal coliform concentrations in waters and sediments were negligible. The data indicated an environment relatively free of terrestrial influence.

Heavy metals were not appreciable in water or sediments, but certain chemical species were evident in some biological components of the ecosystem. Copper and iron appeared to be accumulating in sand dollars in and southwest of this interim disposal site. However, as a result of these findings, we feel further investigation is warranted.

Chlorinated hydrocarbon concentrations in sediments were found to be negligible.

"Dark flaky" material observed by underwater television may be ferric hydroxide originating at an acid waste dumpsite approximately 10 miles northwest, suggesting interaction between the two sites.

In addition to the characterization of the physical, chemical, and biological aspects of the dumpsite, the objectives of this survey included (a) development of a practical scheme for monitoring ocean dumping practices and (b) gaining additional insight into the continental shelf environment. Both the sampling scheme and analytical techniques employed during this study have future applicability to other sites on the continental shelf. In conjunction with published data of regional scope, this brief yet intensive study has provided a detailed picture of the spring conditions at a mid-shelf site. The most troublesome aspects of any shelf study continue to be the difficulty of determining accurate position at sea (for re-occupation of stations) and the lack of current speed and direction data throughout the water column.

I. INTRODUCTION

World population is, and will continue to be, highly concentrated in the coastal zones of the continents. Within the United States, approximately fifty-five million people live within a fifty mile belt along our coastline. This zone, comprising some 8% of the total land area, supports about 30% of our population. At present, population and industrial activity within the coastal zone is increasing at a rate of about 2.5% per year, and the trend is expected to continue. Such growth places a heavy burden on municipal services, especially waste disposal. Many coastal cities have found the discharging of municipal sludge into the ocean and its environs as the most practical alternative to land disposal.

Ocean disposal appears to be a more attractive means of disposal for several reasons. Wastes "disappear" from view, they are generally diluted quickly by the sea, and the only cost is that of transporting waste to the site. To further minimize transportation cost, dumping is frequently done close to shore. This practice has generated extensive concern and subsequent protests from coastal communities.

Public Law 92-532, the "Marine Protection, Research, and Sanctuaries Act of 1972," was enacted in part to regulate ocean dumping practices by establishing a permit system which inventories quantity and quality of materials transported to sea for disposal as well as by a monitoring program to continuously assess the effects of these practices at specified sites.

Under this law, the designation of dumpsites and the quantities deposited thereon must be based on a scientific knowledge of the specific environments. While generic information was available for continental shelf environments, the background was sufficient only to design the preliminary steps in a monitoring program.

An oceanographic survey of a proposed interim dumpsite approximately 50 miles off the mouth of Delaware Bay, dubbed "Operation QUICKSILVER," was conceived and executed in spring 1973 with the objectives: (1) attempt to establish ambient environmental parameter levels prior to active dumping at the site, (2) assist in developing a practical monitoring scheme for monitoring of ocean dumping practices, and (3) develop further insight into the continental shelf environment, which seems to be the next province to be assailed by man' s wastes, but which, with foresight and current information can be managed intelligently.

The conclusions contained herein are based on four days of data collection within the area of concern. Obviously, it would be irrational to adopt these data as representing the range of conditions which prevail at this site. Rather, they can be considered characteristic of the oceanographic regime for the spring season. Final evaluation of the suitability of this site for waste disposal must await further study which will reveal seasonal changes in the biota and watermass. The introduction of an unnatural perturbation (solids and fluid wastes) will require reassessment of its effect on the marine ecosystem. The concepts of accumulation and assimilation can then be considered.

Unfortunately, man' s activities can and have altered natural processes, often with adverse results to himself (the user and ultimate beneficiary of the results) and more immediately to the other occupants of the environment which he alters. An appropriate monitoring program at ocean disposal sites would provide suggestions on how we might establish an acceptable balance between our human needs and the finite capacity of the ocean to satisfy them.

II. BACKGROUND

A. LOCATION

The site selected as an interim dumpsite for the disposal of municipal sewage sludge lies midway across the broad continental shelf off Maryland. It is thus centrally located in the region termed the Chesapeake Bight (Norcross and Harrison, 1967) which occupies the southern half of the Middle Atlantic Bight between Nantucket and Cape Hatteras. The western edge of the dumpsite is set by a line passing through 74°20' W longitude, a meridian which lies 67 km (36 nautical miles) east of Ocean City, Maryland. The northern and southern boundaries lie on latitudes of 38°25' N and 38°20' N, respectively, and the eastern edge of the area falls on the meridian along 74°10' W longitude. Thus, the entire 172 km^2 within the designated boundaries of the dumpsite lie within International Waters. The location of this interim dumpsite is shown in Figure 1.

B. PREVIOUS WORK

The paucity of information for relatively small specific sites on the continental shelf has prompted studies such as this survey cruise when localized data are required. However, background information for the Chesapeake Bight reveals regional trends in sedimentation, currents, biota and other environmental factors which are valid generalizations for most sites. The interested reader is referred to the excellent summary volume on oceanographic and biological parameters of the entire Middle Atlantic Bight recently published by the University of Rhode Island (see references for Bumpus, Lynde and Shaw, 1972). The most recent treatment of regional sedimentation within the area of interest

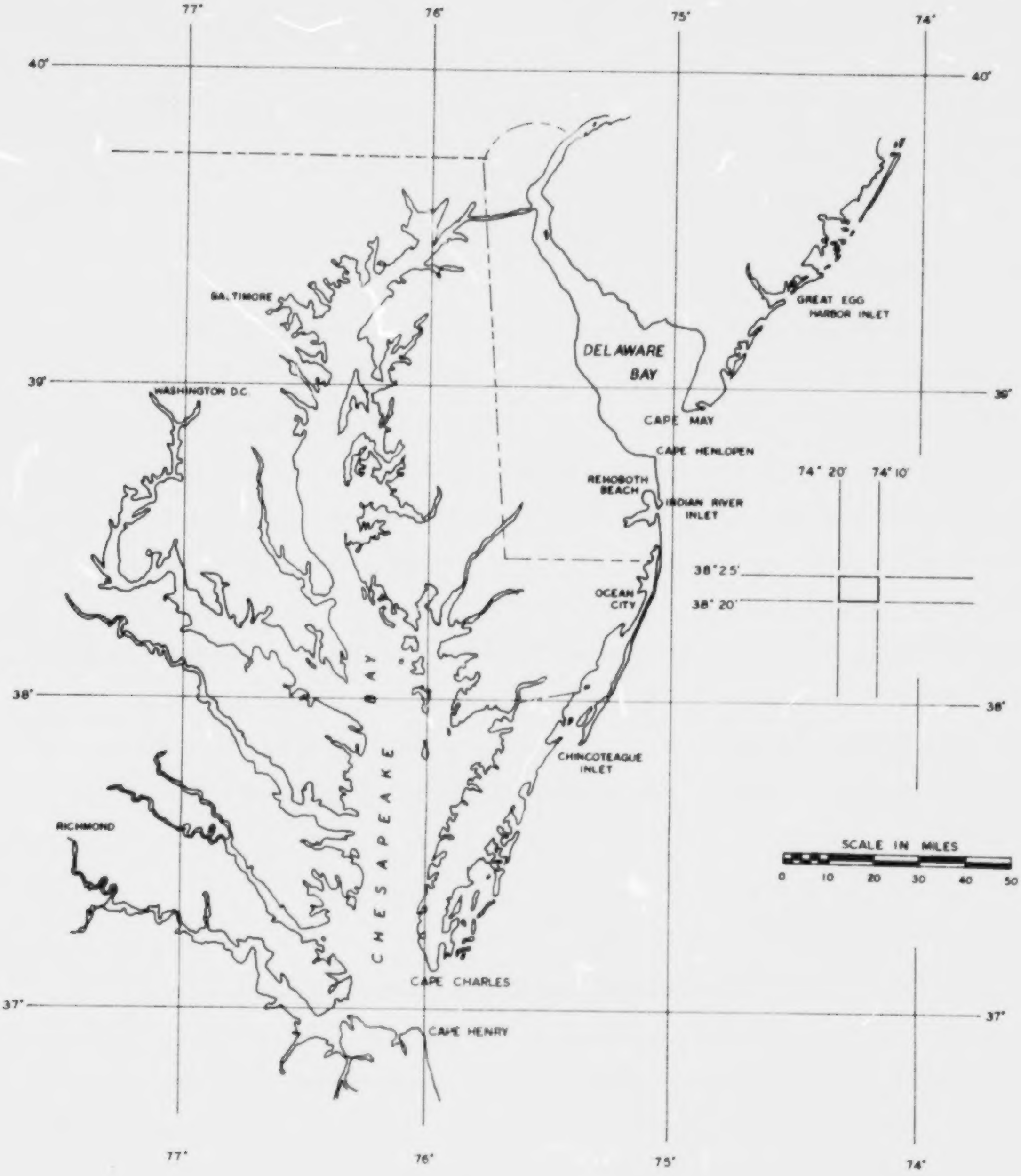

77°
76°
75°
74°
40°
40°
BALTIMORE
GREAT EGG HARBOR INLET
DELAWARE BAY
39°
WASHINGTON D.C.
39°
CAPE MAY
CAPE HENLOPEN
REHOBOTH BEACH
INDIAN RIVER INLET
74° 20'
74° 10'
38°25'
OCEAN CITY
38° 20'
38°
38°
CHESAPEAKE BAY
CHINCOTEAGUE INLET
SCALE IN MILES
0
10
20
30
40
50
RICHMOND
CAPE CHARLES
37°
37°
CAPE HENRY
77°
76°
75°
74°

Figure 1 — Index map for the upper Chesapeake Bight area showing the location of the sludge dumpsite as a rectangle east of the Delmarva peninsula.

is the thorough review of historical data and reporting of extensive new analyses provided by Milliman (1972).

C. SURVEY CRUISE

The baseline study of the designated dumpsite was initiated in accordance with EPA guidelines which required a survey of the area prior to the initial release of digested sludge scheduled for 8 May 1973. Accordingly, the R/V ANNANDALE (Figure 2) was chartered for a five-day period to commence 1 May 1973. The ship departed Lewes, Delaware at 1121 hours 1 May, and returned to Lewes on 5 May at 1600 hours. Eleven stations were occupied, but activities at one (Station 3) were cancelled in order to evacuate a member of the party who had become ill. Biological samples were obtained from Station 6, but no bottom materials were recovered at this site. The scientific log of events during the cruise is included as an appendix to this report. Ship's track and station locations are shown in Figure 3.

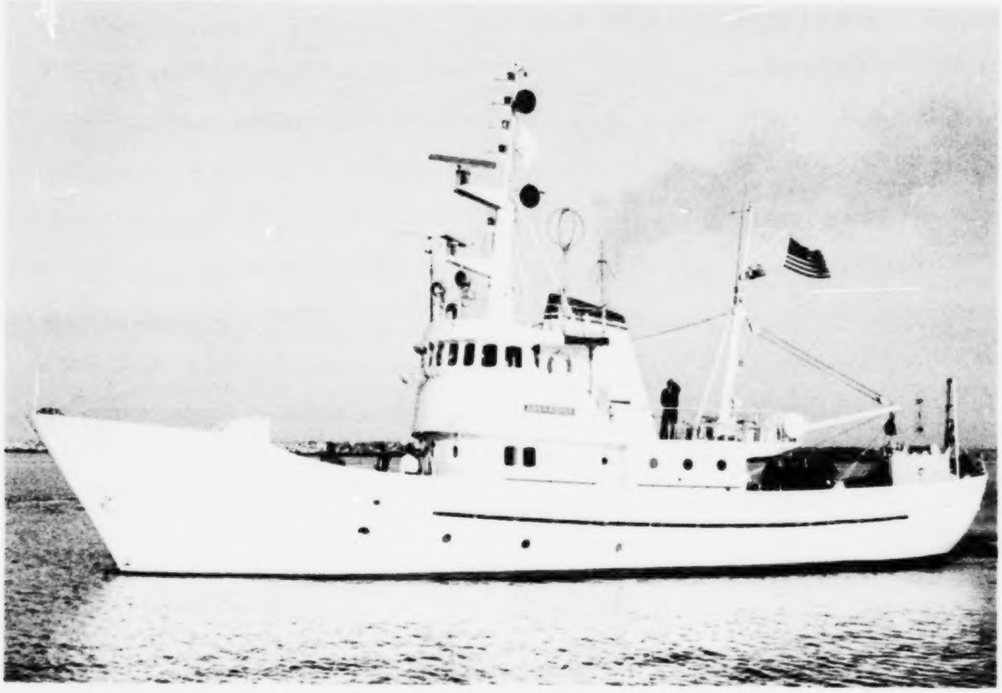
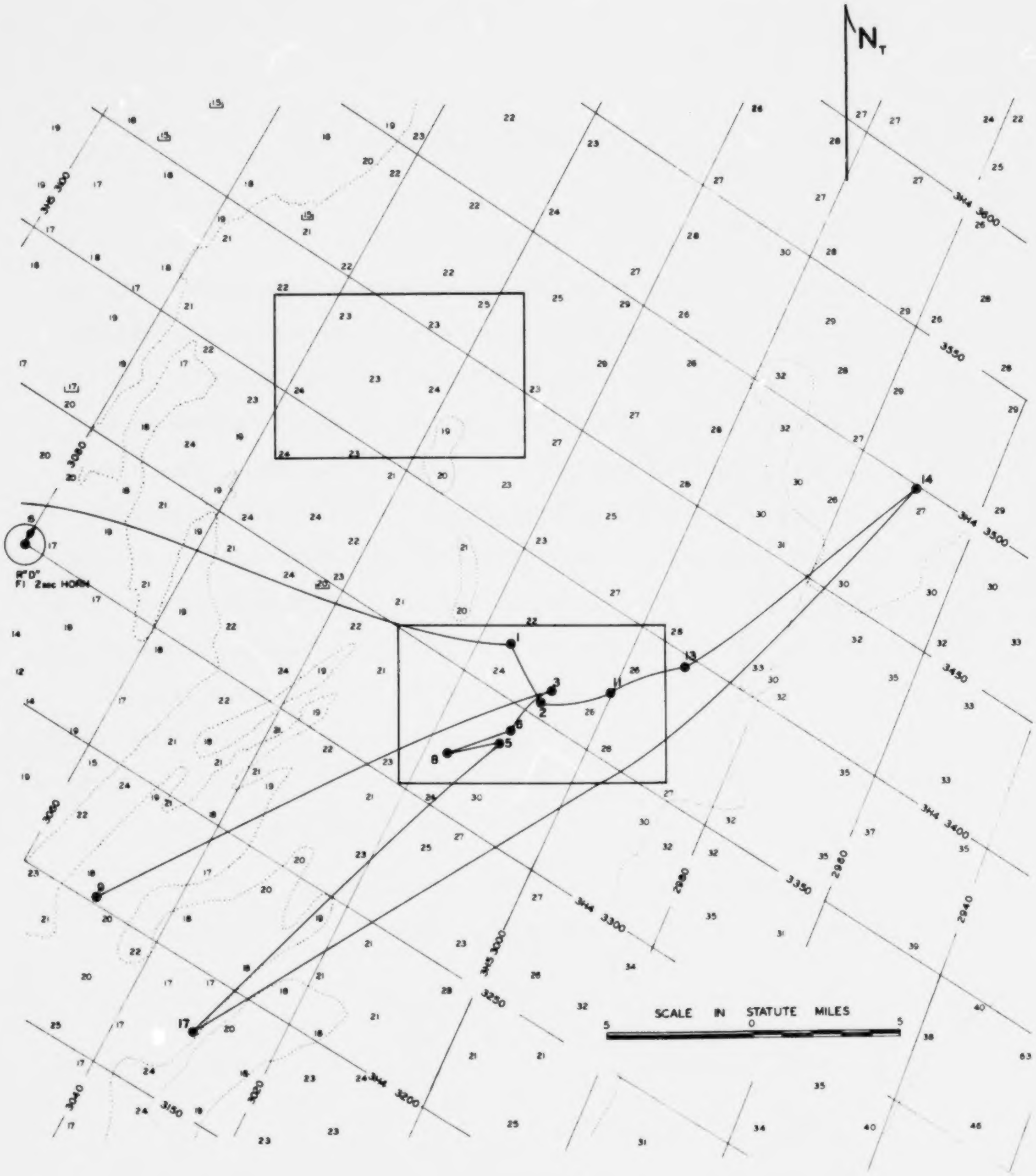


Figure 2 — R/V ANNANDALE.



N_T
3H5 3100
3H4 3500
3550
3H4 3500
3450
3H4 3400
3350
3H4 3300
3250
3H4 3200
3150
3080
3060
3040
3020
3H3 3000
2980
2940
R "D" Fl 2sec HORN
1
2
3
5
6
8
9
11
13
14
17
SCALE IN STATUTE MILES
5
0
5

Figure 3 — Dumpsite location map, showing both the acid waste dumpsite area (northern rectangle) and the sludge dumpsite investigated during this study. Stations are marked by solid circles; the solid line shows the vessel track for the cruise.

III. BATHYMETRY

A. PREVIOUS WORK

A number of editions of bathymetric charts have been prepared for the Middle Atlantic Bight area, but most have contour intervals which yield little or no information regarding the degree of relief within the dumpsite area. The most detailed chart for this area is that prepared by Franklin Sterns for the ESSA group of the Department of Commerce (see Sterns, 1967). Chart 0807N-56, the Baltimore and Wilmington Canyons sheet of the series, displays the relief of the sea floor with a contour interval of one fathom (6 feet or 1.83 m). The portion of that chart occupied by the designated dumpsite is reproduced in Figure 4. Soundings employed by Sterns for this portion of the chart were taken from the U.S. Coast and Geodetic Survey's Hydrographic Survey No. H-5350 conducted in 1933. Although forty years have elapsed since this survey was completed, the accuracy is considered quite good even by today's standards. Statistics for the survey yielding the chart appearing in Figure 4 are:

Mean distance between track lines (nautical miles)	0.5 to 1.5
Standard deviation of isobath position error (nautical miles)	0.2 to 0.3
Standard deviation of isobath depth error (here termed "Crossing Error") (fathoms)	Good (<1 fm) to Fair (1 to 8 fm)

B. SURVEY CRUISE

Echo sounding traverses of the dump site area were performed during evening hours of the cruise. The echo sounding equipment aboard the R/V

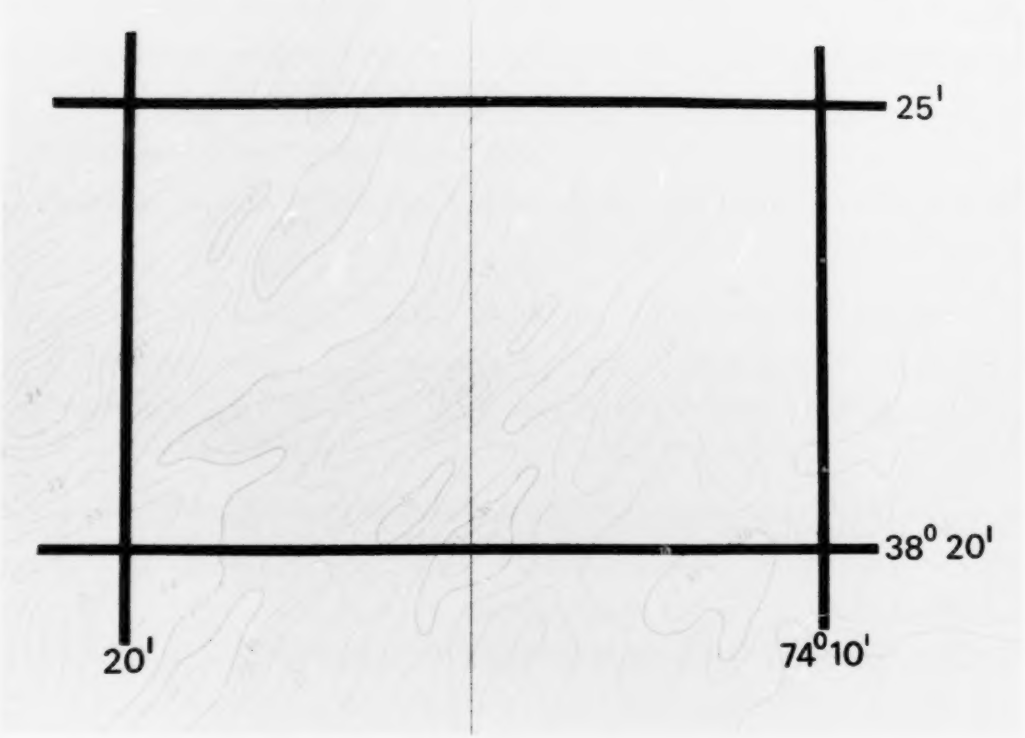


Figure 4 — Bathymetric chart, prepared by Sterns (1967) for ESSA chart series in the northern Atlantic continental shelf. Contours are in fathoms at a 1-fathom interval. Based upon precise survey of 1933.

ANNANDALE consisted of a Kelvin-Hughes variable scale recording unit with adjustable timing (paper speed) for scale. Examples of the recordings for selected lines appear in Figure 5. Examination of these records was correlated with positioning logs which recorded the depth at one-minute intervals and the Loran A position at five-minute intervals. Corrections were made for keel depth (depth of the echo sounder transducer below the water line) and for tide (based upon time of day and predicted tide for coastal Maryland).

The results of a compilation of 150 km of sounding lines is presented in Figure 6. If we compare our statistics with those parameters cited by Sterns, we note:

Distance between track lines (nautical miles)	0.5 to 1.8
Standard deviation of isobath position error	Not determined
Standard deviation of isobath depth error ("Crossing Error")	1.5 meter (0.8 fm) (Good)

These data indicate that in spite of the difficulties encountered in employing Loran A for positioning, the chart shown in Figure 6 can be considered "good" on the basis of criteria set by the Department of Commerce.

Our analysis of the bathymetric data included a statistical examination of crossing errors compared with time of day and number of intersections (Figure 7). This analysis was performed to evaluate statements made by the scientific party regarding the deterioration of Loran quality during early morning hours, and to assess the degree of crossing errors (see caption, Figure 7). Examination of this figure reveals that crossing errors increase to a maximum between about 0100 and 0400 hours, a factor attributed here to the deterioration of the Loran signal and/or reception during this period. The mean crossing error is at about 5 feet, or 1.5 meters, and almost two-thirds of the crossings are less than 1 fathom (1.8 meters).

It should be noted that the bathymetric chart drawn from data collected on this cruise (Figure 6) was prepared without reference to the existing detailed

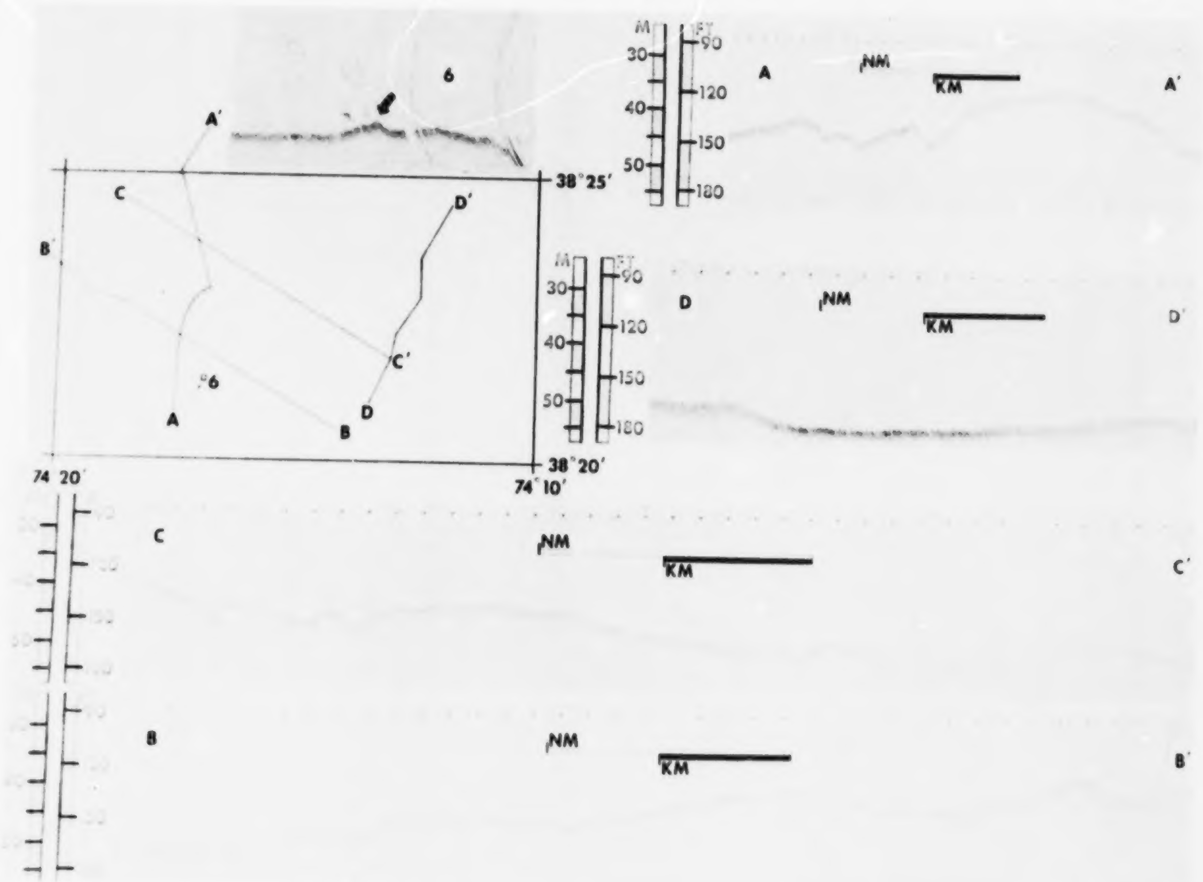


Figure 5 — Echo sounder records from the dumpsite area. Ship's track is shown as inset (left center) and single record for drift over site of Station 6 is indicated by arrow. Horizontal scale and vertical exaggeration vary since recorder was set at different time intervals (small dots along the upper edge of records are minute time marks) for different tracks. Further distortion by curved sweep or recording stylus imparts false asymmetry to relief (slopes facing to right are oversteepened). Vertical scales are in meters (m) and feet (ft.); horizontal scales in kilometers (km, black bar) and nautical miles (nm, white bar).

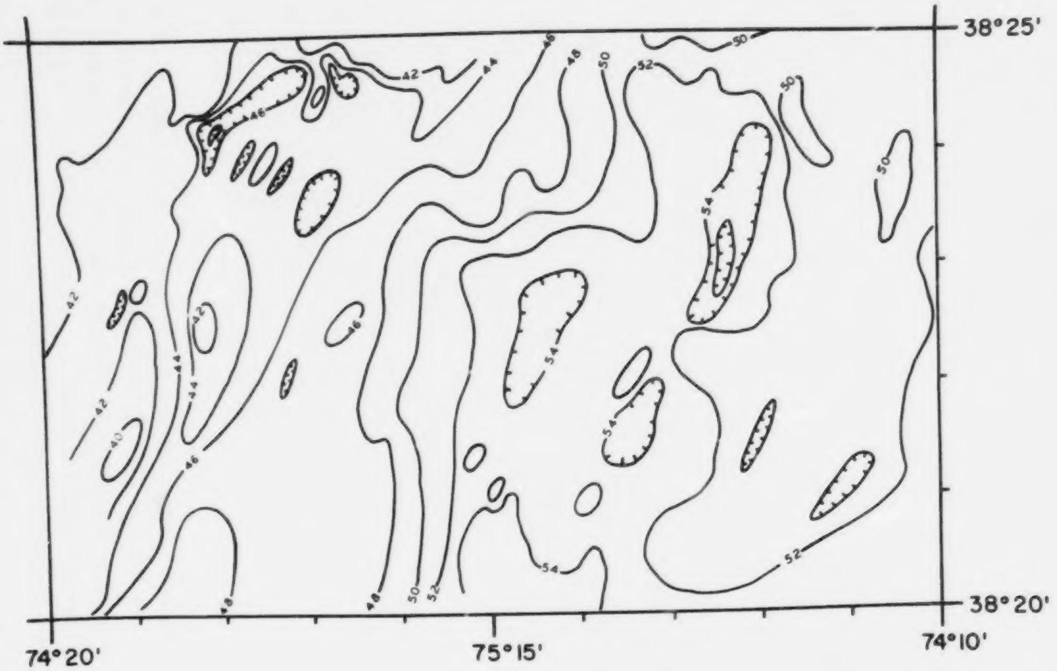

38°25'
38°20'
74°20'
75°15'
74°10'
42
44
46
48
50
52
54

Figure 6 — Bathymetric chart prepared from 150 km of soundings such as those appearing in Figure 5. Contours in meters, corrected for predicted tide and depth of transducer. Closed depressions are hatchured.

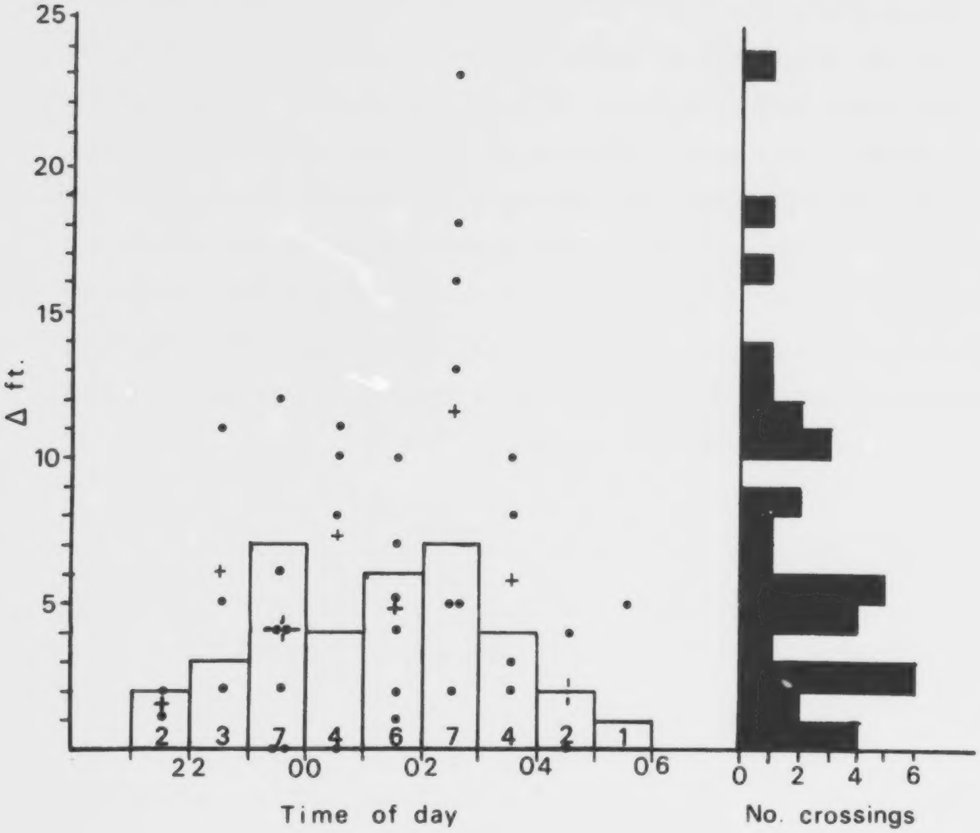


Figure 7 — Statistical review of bathymetric data used in preparing Figure 6. Ordinate values (Δft.) are discrepancy (in feet) of crossing points of tracks which, after removing tide correction, should be zero. Comparison with time of day (abscissa) was made to evaluate Loran deterioration during early hours (see text). Crosses are averages for each hour intervals, numerals at base of histogram bars are number of crossings. Frequency distribution of crossing errors appears at right.

chart (Sterns, 1967). Comparison of the two figures shows that quite a close correlation in depth and general "fabric" or "bathymetric grain" exists between the two surveys even though 40 years separates the collection of sounding data.

The major features of relief, elongate depressions and ridges which are characteristics of the central portions of the continental shelf of the Middle Atlantic Bight (Uchupi, 1968), are apparent in both charts. The origin of these features remains controversial (see, for example, Swift, et al., 1971 for a review) but the interesting fact resulting from this survey is that very little apparent change has occurred over a period of four decades. This suggests some long-term stability to the larger forms of relief which in turn bears upon the fate of materials deposited in the region.

C. MICRORELIEF

As used herein, the term "microrelief" will be employed to describe features which can be resolved via television imagery. It includes ripple marks, biological excavations, etc., and is thus at the lower end of the microtopographic spectrum as defined by Laughton (1963) who includes features from 50 m to 1 mm. The echo sounder records, although capable of displaying features having relief of 0.3 m, in general appear to be relatively smooth once the wave effect is removed (see Figure 5). One small feature (ridge) appears as a conical surface at Station 6, but it would have probably been overlooked had the ship not been drifting (slower speed tends to improve resolution of small features). The sharp ridges appearing in traces reproduced in Figure 5 are due, in part, to the distortion of the curved scribe on the instrument, but also reflect the presence of low linear ridges throughout the area.

On a finer scale, the television pictures reveal the presence of ripple marks and biological excavations at a number of stations (Figures 8, 9, and 10). The general shape of the ripples is subdued, and it is not possible to determine if they are symmetrical (oscillation ripples) or asymmetric (current-induced

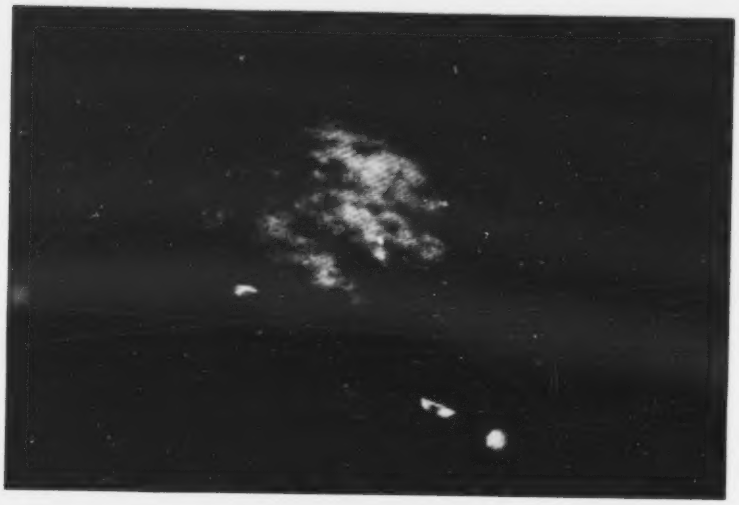


Figure 8 — TV monitor photograph of sea floor at Station 2, center of dumpsite. Dark bands are fine sediments in troughs of ripples; dark dots are sand dollars. Note white clam shells, concave-up in ripple troughs. Largest clam shell is 8 cm long. Scale factors for television stills was provided by D. Maurer from statistical analyses of sand dollar diameters.

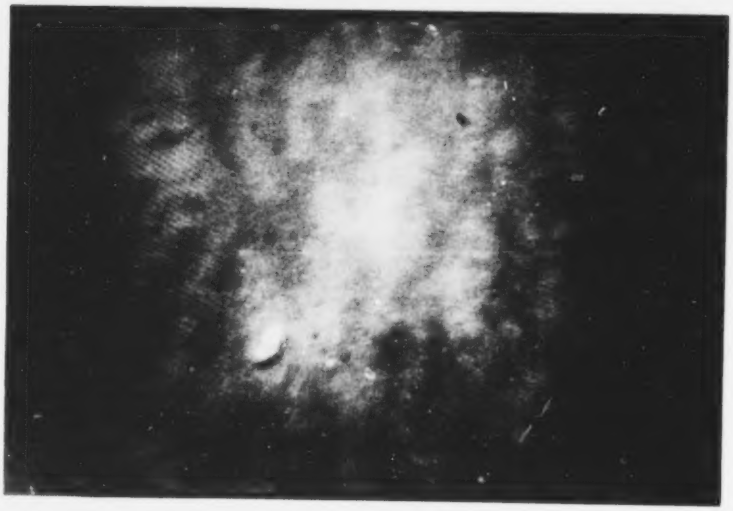


Figure 9 — Rippled bottom at Station 9. Clam shell at lower left is about 7 cm long.

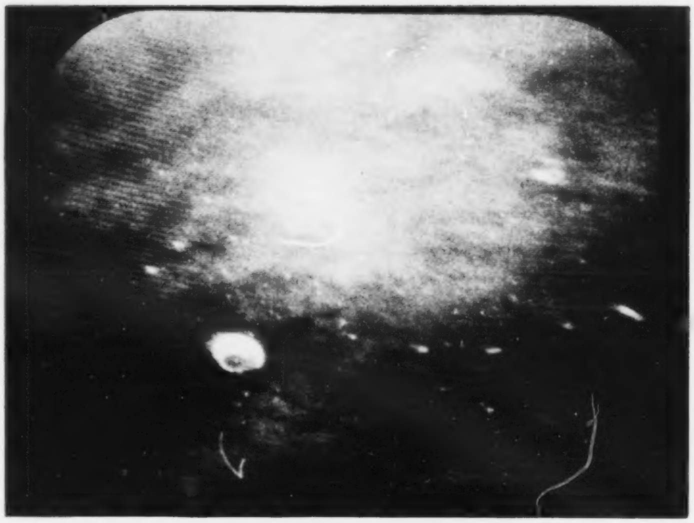


Figure 10 — Gently undulating bottom at Station 5. Ripples are subdued, and little relief is present. White clam shell at lower left is 10 cm wide, and contains fine sediment. Note concave-up attitude of clam valves in this view, a feature which was commonly noted at all stations where whole shell debris was present.

ripples). In either event, their presence implies the existence of bottom currents of a magnitude sufficient to initiate motion (see Section V on Currents). Biologic activity has generated small craters, tracks and mounds which, at many stations, are the dominant form of microrelief.

IV. SEDIMENTS

A. PREVIOUS WORK

Regional studies of sediments of the Atlantic Continental Shelf have been completed by various workers beginning with the work of Pourtales in 1870 (see Milliman, 1972). Sampling grids for such studies are invariably large, and in light of our present knowledge of sediment distribution on the shelves, they can only provide gross characteristics of a region. One such study (Milliman, 1972) is reported from the extensive survey of the Atlantic Continental Shelf conducted by the Woods Hole Oceanographic Institute and the U.S. Geological Survey. A station from this survey lies within the dumpsite, and the various parameters relating to sediment character can be cited as representative of the area.

Regional sediments are considered coarse to medium fine sand in the modal size class (the most populus size fraction), that is, the sand fractions have a general size of from 1 to $^1/_4$ mm in diameter. Gravel (particles with diameters greater than 2 mm) can account for up to 25% in the western third of the area, but much of this may be due to shell fragments and not mineral or lithic (rock) fragments. More than 90% of the sample consisted of quartz or feldspar, with more than half of the grains exhibiting iron staining which imparts a characteristic orange-brown coloration to the coarser sands. Glauconite makes up from 1 to 5% of the sample, and calcium carbonate accounts for a like amount. Of the carbonate portion, most of the material consists of echinoid and mollusk fragments of shells, spines, etc. with benthonic foraminifera accounting for less than 5%.

B. THIS SURVEY

Examination of the 9 sediment samples from the survey stations revealed properties generally similar to those described by Milliman (op. cit.). Textural parameters are presented in Table 1, and cumulative curves for the sand fractions, as determined by settling tube analyses (Cook, 1969; Felix, 1969; Gibbs, 1972), appear in Figure 11.

Two examples of sediment samples are presented in Figures 12 and 13. It is obvious from these photomicrographs that the coarser-grained components are more angular, while the well-sorted finer materials contain more rounded grains. Coloration is also a function of size, the coarser grains stained a deep orange to brown while the finer sediments display high percentages of clear unstained minerals. Although diagnostic staining techniques were not employed during the inspection of sand fractions, visual estimates of mineralogy indicate at least 90% of all samples consist of quartz. Accessory minerals include a glossy black variety of glauconite and pale white to pinkish feldspars.

C. INTERPRETATION

Examination of Table 1 will reveal a correlation between depth, mean diameter and sorting. The deeper stations (2, 13, and 14) yielded sediments having a generally finer and better sorted nature than the samples from shallower depths. There can be several explanations for such a situation.

Inasmuch as wave energy which reaches the bottom is attenuated with increasing depth, the reduced velocity of wave-induced surge could be reflected in the nature of sediments as depth increases. Finer sediments should be expected where wave energy is reduced, since larger particles would remain in place as the wave-induced current speed diminished with increasing depth. Similarly, it should be noted that for some time sedimentologists have shown that finer sands are commonly better sorted than coarser fractions (Inman, 1949). This situation reflects the differences in threshold velocity (the current required to initiate movement of a sand particle) for given sand sizes.

Table 1. SEDIMENT SAMPLE DATA

Station	Depth (ft)	Depth (m)	$M\phi$[1] (0 to 4ϕ)	$\sigma\phi$[2] (0 to 4ϕ)	Deviation[3] (0 to 4 ϕ)	% Coarser than 3ϕ (0.125 mm)	% Coarser than 0 ϕ (1 mm)
01	156	47.5	1.28	0.68	Moderately well sorted	99.8	11.63
02	177	53.9	2.40	0.30	Very well sorted	95.7	5.03
05	150	45.7	1.03	0.58	Moderately well sorted	99.7	38.89
08	130	39.6	1.25	0.50	Moderately well sorted	98.9	18.64
09	110	33.5	1.30	0.60	Moderately well sorted	98.3	34.78
11	170	51.8	1.38	0.58	Moderately well sorted	99.1	26.88
13	170	51.8	2.18	0.28	Very well sorted	99.7	10.9
14	173	52.7	2.25	0.20	Very well sorted	99.4	1.11
17	125	38.1	1.50	0.45	Well sorted	99.4	4.25

1. $M\phi$, or mean diameter, of a sediment sample is one-half the sum of the 16th percentile and 84th percentile. It approximates the central tendency, or "average" size of a sample (after Inman, 1952). Phi (ϕ) units are used to indicate size according to the relationship (ϕ) = $-\log_2$ (diameter in millimeters). This convention avoids awkward fractional notation and permits simplified plotting of size data on arithmetic scales (see Figure 11).

2. $\sigma\phi$, or "sorting", measures the degree of scatter, or "spread", of a cumulative frequency curve with regard to its central tendency (mean). It reflects the standard deviation based upon half the difference between the 84th and 16th percentiles (Inman, 1952). Sorting provides a measure of the range of conditions present at a site such as the range in velocity, degree of turbulence, etc. The greater the $\sigma\phi$ value, the broader the range of conditions which affect the overall sediment character at a site. Low values indicate fairly uniform conditions.

3. Verbal modifiers of sorting have been established (Friedman, 1962) to facilitate discussion of sediment statistics. The following ranges apply to the sand fractions from this study, all of which display a relatively high degree of sorting for the marine environment:

$\sigma\phi$ 0 - 0.35 = very well sorted
$\sigma\phi$ 0.35 - 0.48 = well sorted
$\sigma\phi$ 0.48 - 0.75 = moderately well sorted

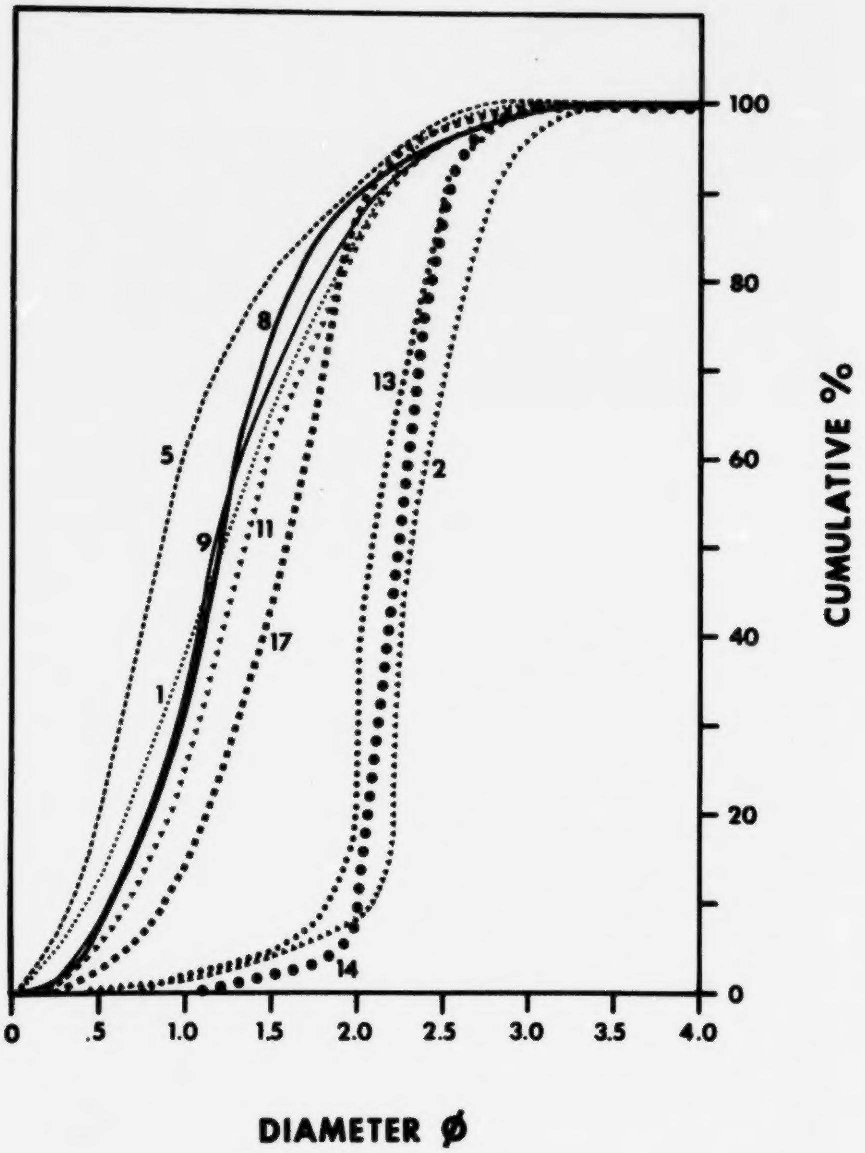


Figure 11 — Cumulative frequency curves for the sand fractions of sediment samples. Numbers indicate station. Phi values are based on log diameter, in mm, of grain sizes (see text). The more vertical the curve, the fewer grain sizes are present (the better the sorting). Fine grained components (0.062 mm diameter, or 4 ϕ) were not present (see Table 1). Fraction greater than 1 mm (0 ϕ) diameter not included.

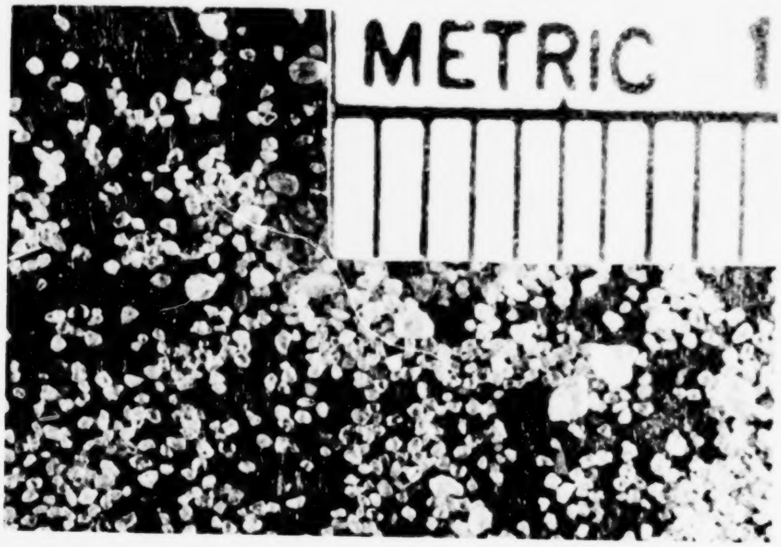


Figure 12 — Photomicrograph of sand fraction from Station 2. Note well sorted nature of the sands, and general roundness of many grains. Most of the particles visible here are clear quartz (compare with Figure 13).

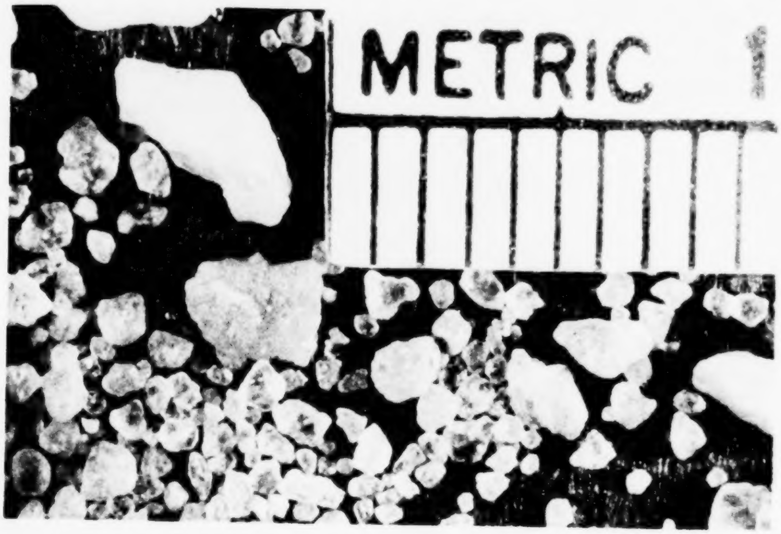


Figure 13 — Photomicrograph of sand from Station 11. Note angularity of larger grains and variety of sizes present (poorer sorting than sample from Station 2, Figure 12). Compare cumulative frequency curves for these two samples in Figure 11.

Fine sand (0.25 to 0.125 mm, or 2 to 3 ϕ) is the sediment size class most easily moved by water, and thus this size class is generally the first to move under accelerating currents and the last to come to rest under waning currents. In this manner, other size fractions are preferentially removed, that is, simply "left behind." The result is a reduction in the standard deviation, or sorting, of the total size range within the finer deposit.

In summary, we might attach environmental relevance to the fact that in some areas, regardless of depth, sorting values are quite low (well sorted). This may be significant to dumping practices, since these regions probably reflect sites where net turbulent energy at the sea floor is at a minimum. If we assume that the bottom is periodically affected by wave-induced surge, there would be occasional intervals of stirring and resuspension of bottom materials (see Section V on Currents). Locations where finer, well-sorted materials are found would be the sites least affected by such disturbances, and would thus be the regions where matter settling from the sludge plume to the sea floor would be least likely to be resuspended. In this context, these regions could be considered the "sinks" of the dump site area. Further discussion of bottom currents inferred from the properties of microrelief and sediment texture can best be examined in the context of the next section which describes the currents of the area.

The discussion of sediments herein has been restricted to bottom materials. Inasmuch as no samples were taken for analyses of suspended sediments, we have not included a description of work in this field. In an attempt to determine the distribution and nature of suspended sediments within the dumpsite area, seven sediment traps, consisting of a cylindrical container suspended at various depths on a buoyed line, were left at Stations 1, 2, 3, 5, 8, 11, and 14. The surface marker consisted of a red sphere approximately 0.8 m diameter. Tugboat operators towing sludge barges to the site have been asked to look for these markers since dumping began in early May. The markers have yet to be sighted, and they may have broken free or have been vandalized by fishing vessels which frequent this area.

V. CURRENTS

A. PREVIOUS WORK

Studies of currents on the continental shelf within the area defined by Figure 1 are scarce, probably because nearshore problems have generally taken priorities and because it becomes increasingly expensive, from the standpoint of ship-time, positioning and high probability of loss, to install recording current meters at sites tens of kilometers from shore. For these reasons, most workers have resorted to "expendable" devices such as surface and sea bed drifters to resolve regional current patterns.

An excellent summary of surface and bottom currents is provided by Harrison and his co-workers (see Norcross and Stanley, 1967) and by Bumpus, Lynde and Shaw (1972). The most recent regional review is that of Bumpus (1973), while McClennen's work (1973) cites observations from fixed current meter installations positioned 1.5 to 2 meters above the sea floor. Both the Lagrangian technique (drifters) and the Eulerian method (fixed meters) yield essentially the same conclusion: residual currents at the sea floor move toward the southwest at a rate of from 1 to 2 km per day. In the case of drifters, the interpretation is necessarily subjective [see an excellent discussion by Riley and Ramster (1972)], but McClennen's observations at a sea floor site some 75 km north of the interim sludge dump site show that over a 213-hour period of summer observation currents trended toward the south-southwest with a mean speed of 12 cm/sec. His data represent, to our knowledge, the only documented long-term Eulerian measurements of mid-shelf sea floor currents.

B. SURVEY CRUISE

Current measurements were taken from the vessel during the course of the cruise.

1. Shipboard Current Measurements

a. Procedure —

Current measurements were collected during the survey cruise by freely suspending an instrument from the anchored research vessel. The instrument used was a Magsine current meter manufactured for the University of Washington, consisting of a Savonius rotor, case attached vane, and deck read-out module. Generally, the characteristics of the rotor include a threshold velocity of 2.5 cm/sec, a response time of about 5 seconds (acceleration being faster than deceleration), and equal response from flow in any direction. The vane has a length of 30 cm.

The true current values were confused by vessel motions which, because of wind and sea conditions during much of the cruise, were large compared to the currents to be measured. Unequal response of acceleration and deceleration produced unnaturally high readings. Adding to the problems of vessel motion were limitations in the vessel's mooring gear. Only one anchor could be used and only three shots (82 m, 270 ft) of chain were available. The resulting insufficient scope caused the periods of "horsing" about the anchor to be shorter than desirable and often let the vessel drag its anchor. The latter condition would result in unnaturally high current readings as the vessel drifted with the wind and sea rather than with the current.

The intervals at which measurements were taken during a cast were 2 meters for the surface, 10 meters, then 5 or 10 meters at greater depths. The measuring depths were held approximately 60 seconds. Visual averaging was considered necessary during these periods as short term fluctuations were at times ±30% of the speed reading and 60° or more in direction.

b. Results —

Of four deployments of the current meter attempted, two were aborted because of excessive wire angle. The data obtained from the two successful stations (14 and 9), corrected for local magnetic variations, appear in Tables 2 and 3; see Figure 1 for station locations.

During the period over which these measurements were made the wind was generally from the south to southwest at from 16 to 28 knots, about opposite to reported currents for this area.

A visual observation was made of the sediment trap buoy at Station 9 indicating a southwesterly surface drift, in spite of a breeze blowing in the opposite direction. This observation is in conflict with the current meter reading taken at 3 meters, which has the current almost north.

Duplicate readings were taken at two points on the upcast to verify the reading at that depth. Poor repeatability was indicated. While current speed for these comparisons was within ±0.03 knots, direction varied by 75° and 38° for the two tests.

c. Discussion —

Neither profile shows any uniform velocity or directional shear presumably because of the disturbance introduced by vessel motion. One of the most notable features of these profiles is the fact that current speeds do not diminish rapidly with depth, but rather vary within the same limits to the depth to which readings were taken.

The two profiles were made 10° out of phase on the tidal cycle, if the 35 nautical mile spatial difference between the stations is not considered. An attempt was made to arrive at a mean motion value from these profiles. Assuming that there is a uniform mean motion unchanging with depth, the errors introduced by vessel motion would tend to be equal in all directions provided enough measurements were made. In performing a vector averaging operation on these readings, error components should tend to nullify each other.

Table 2. CURRENT SPEED AND DIRECTION - STATION 14 - 2017 HOURS - 2 MAY 1973

Depth, m	Speed, cm/sec.	Direction ° True
3	18.0	200
5	19.5	170
7.5	23.2	180
10	24.2	222
15	15.4	200
20	13.9	140
30	7.2	101
40	9.3	282
50	19.0	215

Table 3. CURRENT SPEED AND DIRECTION - STATION 9 - 1013 HOURS - 4 MAY 1973

Depth, m	Speed, cm/sec.	Direction ° True
3	14.9	355
5	27.3	347
7	21.6	342
9	25.7	339
11	19.5	235
13	19.5	210
15	26.8	198
20	20.6	179
25	28.3	228
30	26.8	230

The results of vector averaging the reading from the two profiles as well as simple arithmetic means for these values appear in Table 4.

Table 4. CURRENTS BY VECTOR AVERAGING*

Station	V Averaging Speed cm/sec.	V Averaging Direction ° True	M Averaging Speed cm/sec.	M Averaging Direction ° True
14	13.4	192	16.6	190
9	10.8	248	23.1	261

*Components of semidiurnal rotary tidal currents were not determined.

d. Summary —

Best estimates of currents during the time period covering the survey cruise are:

1. Speed about 13 cm/sec (0.25 knots, 11 km/day) fairly uniform over the bulk of the water column.
2. Direction between 192° and 248° true.

2. Shipboard Current Observations

In addition to the actual measurement of currents during the cruise, two other modes of qualitative current information were deduced from additional sources: (a) videotapes of the television bottom traverse from each station and (b) sediment texture (grain size statistics).

a. Videotapes —

In all, several hours of videotape were recorded at the stations occupied during this cruise. Scrutiny of these tapes and the logs and the commentary of scientists observing the on-deck monitor were used in the interpretation of visual data which might relate to local currents at the sea floor. The following observations bear upon the current regime:

1. Most of the shallow stations (depths less than about 50 m) displayed ripples and other features which indicate disturbance (displacement) of the local sediment. Most stations also exhibited evidence of bioturbation (tracks, mounds, craters, etc.) suggesting that once the currents which form ripples abate, biological activity should smooth and ultimately erase the ripples. From the videotapes it was impossible to tell if the ripples were symmetric (oscillatory or wave-induced current ripples) or asymmetric (current or unidirectional flow ripples).

2. During the latter portion of the cruise, the weather deteriorated and seas became uncomfortably high. No records were taken of wave period, height, and length but continued television monitoring of the sea floor revealed no turbidity or other current effects which could be attributed to the surface roughness. We assume that the wave length must have been too short to have induced suspension of bottom materials.

3. At many stations, single valves of pelecypods were observed lying on the bottom with a preferred concave-up attitude (Figures 8 and 10). In addition, many were noted to contain sediment which had obviously settled into them after they assumed this orientation. Inasmuch as the shape of these shells is hydrodynamically sensitive, some inference of current activity can be drawn from the attitude of single valves. Emery (1968) has pointed out that the concave-up attitude is characteristic of low energy environments (low current speeds) on the continental shelf. Strong currents tend to orient single valves in a "streamlined" attitude with the concave side down.

b. Sediment Texture —

From the above observations, it would appear that currents which are capable of disturbing the sea floor at this site are infrequent. Unfortunately, other equally plausible data suggest the opposite.

1. McClennen's (op. cit.) study included examination of box core samples which consist of a volume of sediment removed from the sea floor with little or no disturbance. Pelecypod shells within the upper meter are all concave down,

and bedding features within the cores show conclusive proof of the dominance of physical processes over bioturbation. Although this site is at a depth of 30 meters, the sediment is quite similar to that at the stations on this cruise.

2. Currents measured 1.5 m above the bottom by McClennen reveal that the critical erosion velocity (approximately equal to the threshold velocity) for sands at this station nearest the dumpsite was exceeded about 4% of the time. Because there were no storms during the period of measurement, these water motions were semidiurnal rotary tidal currents which display a maximum velocity toward the southwest. We may anticipate that under storm conditions (see Item 3, below) wave-induced surge will dominate the bottom current regime.

3. On the basis of simple wave equations, for a given average depth of 50 m, we can assume that waves having a period of 11.3 sec or longer and a height greater than 2.2 m will generate currents at the sea floor which exceed the threshold velocity of most sands at the stations on this cruise. Wave statistics from Atlantic City, New Jersey (the closest point of record to the dumpsite) indicate that waves having a period of 11 sec or longer occur 2.6% of the time, while significant wave heights (the average height of the highest $\frac{1}{3}$ of the waves) exceeding 2.2 m occur 3.3% of the time (Harris, 1972). These data cannot be directly applied to this region, but they are indicative of the general wave climate of the Middle Atlantic Bight.

3. Bottom Drift Studies

During the course of the cruise, 680 seabed drifters of the Woodhead design (Woodhead and Lee, 1960) were released within the interim dumpsite area. Table 5 shows the release scheme.

The few recoveries to date are disappointing, especially since the beach population should be at a maximum during this period. However, low recovery ratios appear typical in June, July, and August for previous releases at this distance from shore (see Norcross and Stanley, 1967). For 17 releases,

Table 5. SEABED DRIFTER RELEASES

Time and Date	Station	Numbers	Color	Total Quantity	Recovery (as of 27 July)
1258 2 May	1 nm* NW of 2	001-160	Red	160	1
1446 3 May	8	100	Yellow	100	0
2043 3 May	6	161-320	Red	160	2
0645 4 May	1 nm E of 2	321-480	Red	160	3
		100	Yellow	100	0

*nm = nautical mile (1 nm = 1.85 km)

the average recovery is 16.5%, with a maximum of 34% (March) and a minimum of 4.2% (June). Similarly, at the interpolated drift rate of from 0.3 to 0.9 nautical miles per day, it may be premature to anticipate a low recovery for the May dumpsite release. Of the six recoveries reported, five are from the Wallops Island area in Virginia. One returned from Martha's Vineyard, Massachusetts, is believed to have been picked up, and later discarded, by a fishing vessel. In general, drifter recoveries support the concept of a net southwest bottom drift.

One additional factor bearing upon the return ratio is the monetary reward for the return of information requested on the drifter card. According to Riley and Ramster (1972) the reward is the determining factor in reporting the discovery of drifters.

4. Surface Drifter Studies

During the course of the cruise, 269 surface drifters were released at three stations within the dumpsite. Table 6 provides data on the location and dates of these releases.

Table 6. SURFACE DRIFTER RELEASES

Date	Time	Station	Drifter Numbers	Quantity
2 May	1220	2	9802-9900	98
3 May	1446	8	0377-0447	70
4 May	0845	3	9900-10,000	101

At this writing (September, 1973) no returns have been reported. Cards were to be forwarded to EPA, at Corvallis, Oregon.

C. INTERPRETATION

Conflicting evidence regarding the current regime at the interim dumpsite does not permit definitive conclusions to be drawn regarding the activity present at the sea floor. Factors suggesting both long-term quiescence and periodic disturbances have been presented. If the nature of the sediments is interpreted in light of hydrodynamic factors, we can suggest that areas of finer, well-sorted sediments indicate regions where currents and turbulence are minimal. This tacitly assumes that the present distribution of sediments is a reflection of the contemporary hydraulic regime, that is, currents are effective in shaping the sea floor and transporting sediments. On the other hand, at this distance from shore it might be considered that the sediments present at the dumpsite do not necessarily reflect an equilibrium condition with respect to the present hydraulic regime. Under this concept, the sediments are considered "relict" in that they have been derived from a set of circumstances no longer present at this site. Therefore, the lack of fine materials (silts and clays) and the distribution of coarse sands may not connote a vigorous bottom current, but rather a lack of a source close enough to have provided different materials during the period when sediments of the area were undergoing transport.

This report is not the place to review the continuing controversy between "active" and "relict" sedimentary concepts. The interested reader is referred to an excellent summary of this subject by Swift and others (1971). Their conclusion is that present sediments atop the shelf experience brief periods (days) of intensive movement during storms followed by long periods (months or perhaps years) of quiescence. In view of the visual and analytical data presented in this section, most conflicting factors vanish if this concept of intermittent sediment transport is adopted. Obviously, confirmation of this interpretation must await current measurements taken at the sea floor in the dumpsite area.

VI. CHEMISTRY

A. HYDROGRAPHY

1. Previous Work

Extensive hydrographic observations have been made in the continental shelf waters of the Mid-Atlantic Bight, and have recently been reviewed and summarized by Bumpus (1973) and Fisher (1973). In addition, detailed studies have recently been conducted on a nearby acid waste dumpsite, and some results have been reported (du Pont et al., 1972).

Some data from the du Pont studies indicate waste materials may be prevented from sinking to the bottom when the thermocline is established in this area (du Pont et al., 1972). Bowden (1964) cites work by Folsom, Goldberg and Kline and by Folsom and Vine, that similarly indicates introduced materials may diffuse in horizontal planes to a great degree. This propensity for horizontal transport, and lack of vertical forces, indicates that hydrographic conditions, especially density discontinuities, may be of prime importance in evaluation of environmental conditions on ocean dumpsites.

2. Survey Cruise

Profiles of temperature, salinity, dissolved oxygen, and pH taken by Hydro Products Water Quality Monitor or a Beckman RS-5 induction salinometer are shown in Figures 14 through 18.

Temperature distributions indicate that the vernal establishment of the thermocline was developing, and the discontinuity was generally between 30 and 50 ft (9 to 15 m). A rather severe southwest gale on 3 May apparently did not affect the thermal structure.

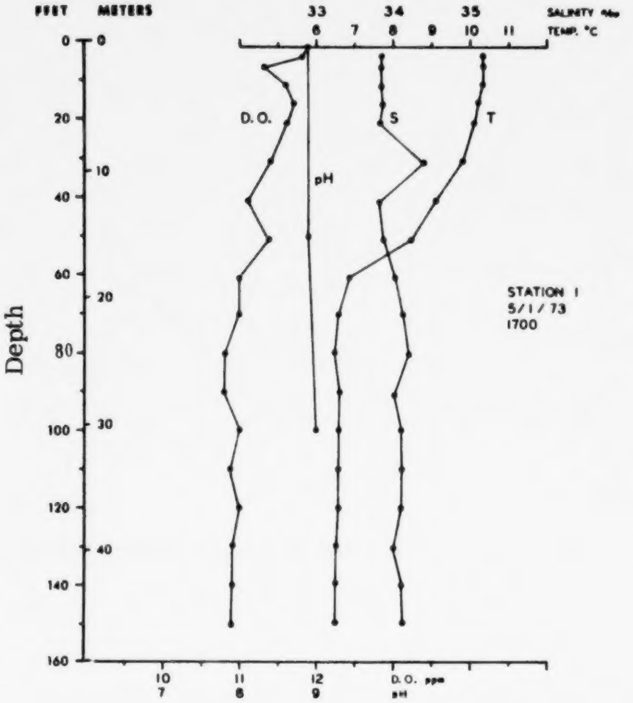


Figure 14 — Hydrographic profile at Station 1, showing salinity, temperature, dissolved oxygen, and pH.

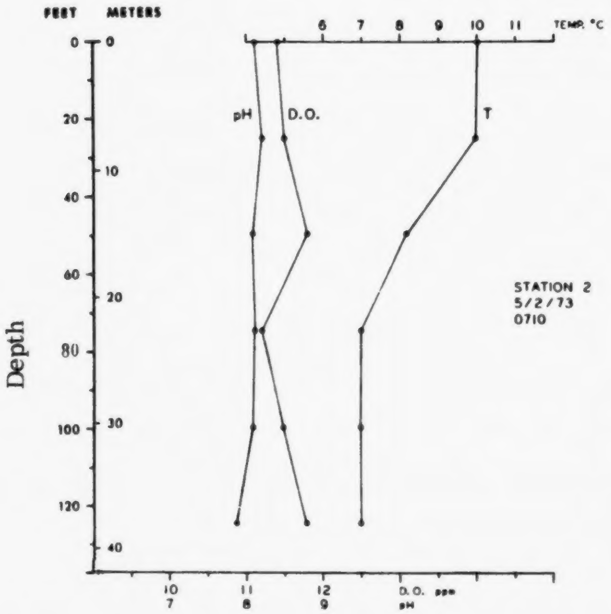


Figure 15 — Hydrographic profile at Station 2 showing distribution of D.O., pH, and temperature

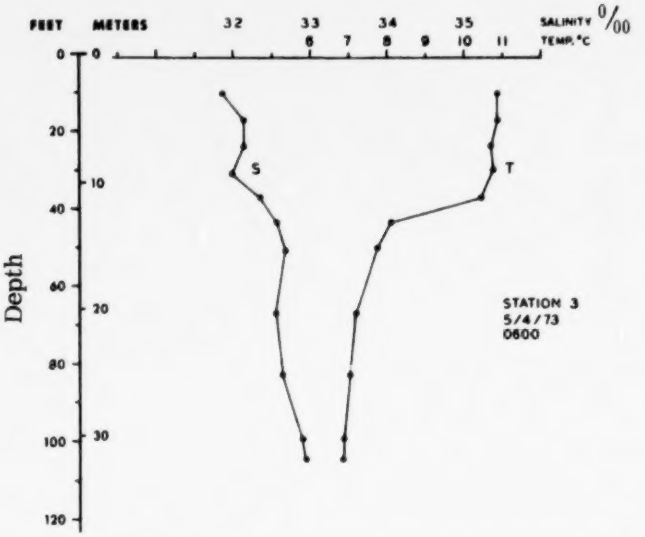


Figure 16 — Salinity-temperature profile of water column at Station 3.

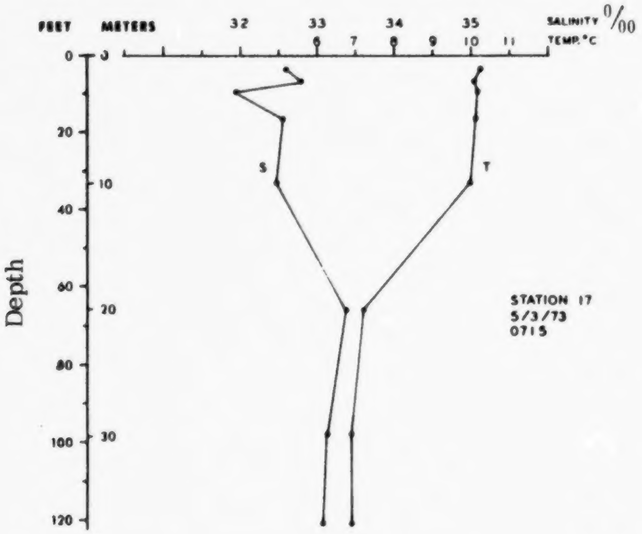


Figure 17 — Salinity-temperature profile of water column at Station 17.

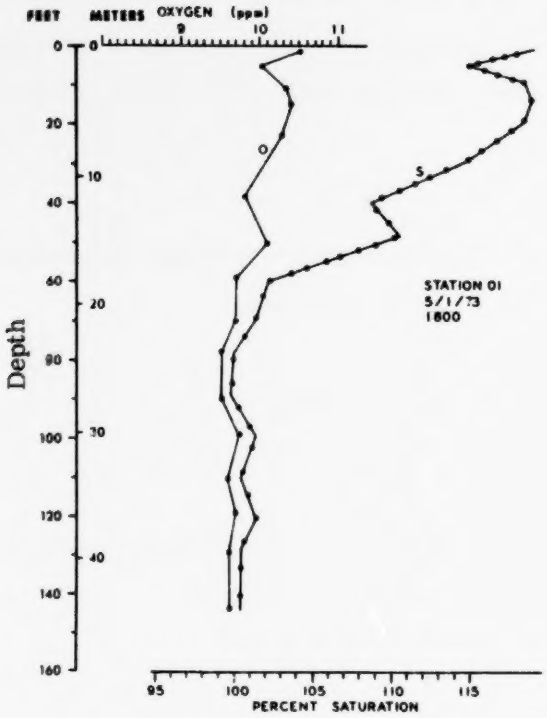


Figure 18 — Distribution of dissolved oxygen (O) and calculated saturation (S) in the water column at Station 1.

Salinity distributions reflect the coastal character of the water and tend to indicate a halocline coincident with the thermocline, with minor perturbations in surface waters. The region generally is affected by runoff from terrestrial sources in the surface layers, and incursion of slope waters at depths (Bumpus, 1973).

Dissolved oxygen was measured with an International Biophysics Company Model 501-001 probe and 490-051 field readout. Percent saturation values were also calculated and are shown for reference in Figure 18. Generally, oxygen values showed no evidence of deficits, and the supersaturation in surface waters is indicative of phytoplankton activity.

The pH values indicated no deviations from values expected in coastal seawater, and were measured primarily because of the proximity of a nearby dumpsite with a history of additions of very low pH industrial wastes.

3. Interpretation

Hydrographic conditions generally reflect the normal patterns expected for these waters under spring conditions.

B. WATER QUALITY PARAMETERS

1. Previous Work

Previous work in the area has recently been summarized by Kester and Courant (1973).

2. Survey Cruise

The data gathered on this cruise were primarily intended to determine background conditions before dumping activities commenced, and as such are not amenable to estimate distributional patterns such as discussed by Kester and Courant.

Water samples were retrieved from 6-liter PVC Van Dorn bottles, placed in 16 oz. polyethylene "Whirl-Paks" and quick frozen in dry ice. Samples were subsequently stored frozen until analysis at the EPA laboratory in Annapolis.

Ammonia determinations gave erratic and apparently unreliable values; consequently they were not included in this report. Recent studies on the preservation of marine water samples for ammonia determinations have shown poor keeping qualities for this parameter (Degobbis, 1973), and ammonia should probably be determined immediately upon sampling.

Nitrate plus nitrite nitrogen was determined by using the Technicon "Autoanalyzer." This procedure utilizes cadmium reduction of nitrate to nitrite and subsequent diazotization with sulfanilamide and N-(1-naphthyl)-ethylenediamine dihydrochloride with the optical density measured at 540 mμ. The results were reported as nitrogen (Strickland and Parsons, 1968).

There are too few data points to draw distributional patterns, but concentrations are generally those expected in this environment (Kester and Courant, op. cit.). Nitrate values vary seasonally with values between 0.07 ppm and 0.007 ppm reported. Nitrite values range from 0.7 to 4.2 ppb.

Total Kjeldahl nitrogen includes ammonia and organic nitrogen and was determined by the standard micro-Kjeldahl procedure. The sample was digested in the presence of strong acid to convert the organic nitrogen to ammonia. The ammonia was then distilled, collected in boric acid solution, nesslerized, and determined colorimetrically. This procedure was automated on a Technicon "Autoanalyzer." The values found agree generally with those reported in other coastal waters (Duursma, 1965).

Total phosphorus was determined after persulfate oxidation of the sample in an autoclave at 15 psi for 30 minutes. The resultant orthophosphate was then determined colorimetrically as the molybdenum-blue complex with optical density measured at 882 mμ. Orthophosphate was determined on a Technicon "Autoanalyzer" (Menzel and Corwin, 1965; Murphy and Riley, 1962). Phosphate concentrations vary from 0.015 ppm to 0.03 ppm.

The concentrations found are in agreement with other observations reported by Kester and Courant.

Silicate was determined on a Technicon "Autoanalyzer" with an automated procedure outlined in Standard Methods (Amer. Pub. Health Assoc., 1971).

Again no distribution patterns are discernible, but agree with other observations in the area (Kester and Courant, op. cit.).

Heavy metals were determined by atomic absorption spectrophotometry at the EPA National Field Investigations Center, Cincinnati, Ohio. No appreciable levels of heavy metals were detected in surface waters at Station 2. Results are shown in Tables 7 and 8.

A supplemental cruise to the dumpsite was made on 14 July 1973 to secure additional water samples for metals analyses. This supplemental cruise was made after dumping activities had started on the dumpsite. (See cruise log in Appendix B.) Water quality parameters are shown in the appendix. Heavy metal analyses were done by the EPA Water Sciences Branch, National Field Investigation Center, Cincinnati, Ohio. No appreciable levels of metals were detected in bottom waters.

C. HEAVY METALS IN SEDIMENTS

1. Previous Work

Metal contents of sediments were determined recently on a site approximately 35 miles from the survey site, and near the mouth of the Delaware Bay (Davey, 1972). The extraction techniques differed markedly from those in the present study, and lower concentrations generally were reported than in the results of this cruise.

Studies by the National Marine Fisheries Service in the New York Bight area, but with stations as far south as Delaware Bay (Nat. Marine Fish. Serv., 1972), show metals contents of uncontaminated sediments comparable to those reported for this cruise.

2. Survey Cruise

Metals were determined from bottom sediments by leaching samples for 6 hrs at 48 to 50°C in concentrated nitric acid, then analysis on a Perkin-Elmer 303 atomic absorber. Mercury was similarly prepared, but analyzed in a Coleman MAS-50 flameless atomic absorber.

The relative concentrations of the various elements are in general agreement with published information, but the concentrations of chromium, zinc, and

Table 7. WATER QUALITY PARAMETERS

Sample No.	Station	Date/Time	Sample Depth ft	NO_2+NO_3 mg/l	TKN mg/l	TP mg/l PO_4	Silica ppm	TOC mg/l
QK7357-0101-1	1	5/1/73 1800	20	0.011	NSQ*	NSQ	0.091	3.92
0102-1	1		75	0.024	0.107	0.048	0.091	4.53
0103-1	1		145	0.026	0.011	0.024	0.101	4.21
0204-1	2	5/2/73 0710	25	0.028	0.338	0.040	0.121	3.59
0205-1	2		85	0.026	0.349	0.040	0.091	3.96
0206-1	2		145	0.021	0.558	<0.01	0.030	4.18
0513-1	5	5/3/73 1112	25	0.026	0.163	<0.01	0.030	3.08
0514-1	5		75	0.030	0.192	0.024	0.101	3.33
0515-1	5		145	0.009	NSQ	NSQ	0.040	0.21
0916-1	9	5/4/73 0905	25	0.021	1.414	<0.01	0.061	2.73
0917-1	9		50	0.024	0.344	<0.01	0.081	5.65
0518-1	9		100	0.032	0.135	0.024	0.111	2.53
1407-1	14	5/2/73 1925	25	0.021	0.163	0.024	0.091	3.32
1408-1	14		100	0.039	0.146	0.064	0.161	3.92
1409-1	14		175	0.021	0.073	NSQ	0.101	2.95
1710-1	17	5/3/73 0715	25	0.026	0.310	0.048	0.050	4.48
1711-1	17		75	0.024	0.270	0.048	0.050	3.55
1712-1	17		120	NSQ	NSQ	NSQ	NSQ	9.05

*NSQ - Not sufficient quantity

Table 8. HEAVY METALS IN SURFACE WATER
(mg/l)

Cd	Cr	Cu	Pb	Ni	V	Be	Hg
<0.02	<0.02	<0.02	<0.1	<0.5	<0.1	<0.2	<0.1
<0.02	<0.02	<0.02	<0.1	<0.5	<0.1	<0.2	<0.1
<0.02	<0.02	<0.02	<0.1	<0.5	<0.1	<0.2	<0.1

manganese are greater. This probably reflects the more rigorous acid extraction procedures employed by the EPA laboratory at Annapolis. Ambient chromium levels seem to be greater than expected, and further pursuit of this phenomenon is indicated. Results are shown in Table 9.

D. CHLORINATED HYDROCARBON ANALYSIS OF SEDIMENT SAMPLES

1. Previous Work

Based upon current available information, there has been no detailed assessment made of the levels of chlorinated hydrocarbons in the marine environment of the Atlantic continental shelf. The only data pertaining to the interim ocean dumping area (other than that presented in this report) come from a paper on PCB residues in the Atlantic zooplankton (Risebrough et al., 1972). Zooplankton taken from an area fairly close to the dumpsite contained 57 ppm PCB (Aroclor 1254) on a lipid weight basis (about 0.22 ppm on a wet weight basis). The highest concentrations occurred near Hudson Canyon and northward to the latitude of New York City where the zooplankton were found to contain about 250 ppm PCB on a lipid weight basis.

While these data indicate fairly high levels of PCB's in waters of the northwest Atlantic shelf, the numbers must be examined with some caution because of the high likelihood of sample contamination from the nets being used (Harvey and Teal, 1973). Previous work examining the addition of chlorinated

Table 9. CHEMICAL PARAMETERS OF BOTTOM SEDIMENTS

Sample	Station	Date/Time	Depth., ft	Volatile Solids, % dry wt.	TKN % dry wt.	Elements, mg/kg dry wt.							
						Cr	Cu	Zn	Pb	Ni	Mn	Hg	Cd
QK7332-0101	1	5/1/73 1800	156	0.32	0.003	2	<1	6	<1	<1	26	<0.01	<1
QK7332-0201	2	5/2/73 0700	177	0.69	0.020	3	<1	9	<1	<1	43	<0.01	<1
QK7332-1101	11	5/2/73 1313	170	0.40	0.009	1	<1	5	<1	<1	32	<0.01	<1
QK7332-1301	13	5/2/73 1530	175	0.56	0.015	3	<1	9	<1	<1	49	<0.01	<1
QK7332-1401	14	5/2/73 1925	176	0.47	0.009	2	<1	9	<1	<1	28	<0.01	<1
QK7332-1701	17	5/3/73 0715	125	0.37	0.005	2	<1	7	<1	<1	27	<0.01	<1
QK7332-0501	5	5/3/73 1112	151	0.30	0.005	2	<1	6	<1	<1	26	<0.01	<1
QK7332-0801	8	5/3/73 1355	138	0.41	0.006	2	<1	6	<1	<1	25	<0.01	<1
QK7332-0901	9	5/4/73 0910	120	0.35	0.006	2	<1	6	<1	<1	3	<0.01	<1

hydrocarbons to the nearshore waters of California through ocean disposal of sewage and sewage sludge indicates that urban sewage and sewage sludge contain relatively high levels of PCB's and, in some cases, DDT (Schmidt, et al., 1971).

2. Survey Cruise

Immediately upon recovery, samples of sediments from dumpsite stations were placed in airtight jars previously rinsed with hexane. Upon return to the laboratory, eight sediment samples were analyzed for chlorinated hydrocarbons by the following method:

1. Air dry, grind in mortar and pass through a 1 mm seive.
2. Extract 100 g Soxhlet 7 hr with 2:1 hexane-acetone.
3. Concentrate the extract (Kuderna-Danish evaporator) and clean with a fuming sulfuric acid-celite column.
4. Concentrate eluant to less than 1 ml (K-D followed by stream of dry nitrogen).
5. Screen with electron-capture gas chromatography.
6. Further clean by passage through an activated aluminum column followed by concentration to less than 1 ml as above.
7. Determine quality and quantity by electron-capture gas chromatography.

The samples gave poor traces when only processed with the acid cleaning, but the aluminum cleaning removed the problems and produced satisfactory chromatographic traces.

Although the PCB's 1242 and 1254 were detected in all eight samples, only in the two highest samples (0101 and 1701) could the numbers be considered above the detection limit. In the case of the other six samples, the values were only one-half to three times greater than values obtained from a reagent "blank" put through the analytical procedures. In all samples, the 1254 peaks closely matched those of standard Aroclor 1254 in number and peak-height ratio. The values for 1242, however, should be considered as estimates (± 100%) because of the poor match with the peak-height ratios of the standard material and the presence of interfering peaks of unknown composition.

The samples were unusually free of the DDT group (DDE, DDD, and DDT), DDE being observed in only one sample and then only at twice the detection limit. Results are tabulated in Table 10.

Table 10. CHLORINATED HYDROCARBONS IN OCEAN DUMPSITE SAMPLES (parts per billion)

Sample No.	PCB Group 1242	PCB Group 1254	DDT Group DDE	DDT Group DDD	DDT Group DDT	Other
QK7334-0101	26	12	ND*	ND	ND	
QK7334-0201	3	1	ND	ND	ND	†
-0501	3	0.9	ND	ND	ND	
-0801	3	0.8	ND	ND	ND	
-1101	3	0.6	0.4	ND	ND	†
-1301	3	1	ND	ND	ND	
-1401	2	0.6	ND	ND	ND	
-1701	23	14	ND	ND	ND	

*ND = Not detectable (probably less than 0.2 ppb)

†These two samples each had a larger unique electron-capture peak not found in the other samples. The peaks did not match any of the commonly found chlorinated hydrocarbons.

3. Interpretation

These samples reflect a very clean area, one most likely completely free of local inputs of chlorinated hydrocarbons. The low values for chlorinated hydrocarbons in these sediments suggest fairly limited biological activity because atmospheric fallout of DDT and PCB would be concentrated by biological activity to yield numbers higher than a few PPB. Chlorinated hydrocarbon analysis of sediments after dumping begins should provide useful information because sanitary and industrial sludges are usually quite high in chlorinated hydrocarbons.

VII. BIOLOGY

A. PHYTOPLANKTON

1. Previous Work

Phytoplankton analyses of the water column in the vicinity of the survey cruise were reported by the University of Delaware, College of Marine Studies (1972). This study indicates that the spring-summer regime (May-October) is dominated by dinoflagellates. This is in general agreement with work done by Mulford in the coastal waters of Virginia (Mulford and Norcross, 1971).

2. Survey Cruise

Phytoplankton samples were taken at surface, mid-depth and bottom for each of six stations near the interim dumpsite. (See Figure 3 for station locations.) Three stations were in the immediate dump area, two inshore of the area, and one 15-miles offshore of the area.

Phytoplankton samples of approximately 250 cc were taken from Van Dorn bottles, preserved in Lugol' s solution and stored in the dark.

In the laboratory, 100 cc of sample were placed in an Utermöhl cylindrical chamber and were allowed to settle until quantitative sedimentation had taken place (Utermöhl, 1936). Microscopic examination of the entire cell was then completed on a Unitron inverted microscope. (See Tables 11 through 16.)

3. Interpretation

Phytoplankton samples were composed almost entirely of dinoflagellates and diatoms. There appears to be a very healthy diversity of genera and this area seems to be typical for this time of year.

Table 11. OCCURRENCE OF PHYTOPLANKTON AT STATION 1

Phytoplankton	Surface	Mid-depth	Bottom
Dinoflagellates			
Amphidinium sp.	14	268	41
Ceratium fusus	26		
Ceratium lineatum	2786		
Ceratium longipes	834	12	
Dinophysis sp.	146	6	
Gymnodinium sp.	14	12	11
Peridinium sp.	50	14	12
Prorocentrum sp.	98	6	1
Diatoms			
Biddulphia sp.			7
Chaetoceros sp.	4	8	5
Coscinodiscus sp.	14	28	39
Diploneis sp.			
Melosira sp.			16
Navicula sp.		20	32
Nitzschia longissima		298	61
Nitzschia sp.		20	22
Pleurosigma sp.			3
Thalassionema sp.			10
Total Dinoflagellates	3968	318	66
Total Diatoms	18	374	196
Total count/100 ml	3986	692	262

Table 12. OCCURRENCE OF PHYTOPLANKTON AT STATION 2

Phytoplankton	Surface	Mid-depth	Bottom
Dinoflagellates			
Amphidinium sp.	27	17	15
Ceratium fusus			
Ceratium lineatum	993	9	1
Ceratium longipes	482	2	
Ceratium sp.	5		
Dinophysis sp.	70	8	
Gymnodinium sp.		4	20
Peridinium sp.	21	2	
Prorocentrum sp.	29	4	1
Diatoms			
Biddulphia sp.	6		
Chaetoceros sp.		2	25
Coscinodiscus sp.	5	36	64
Cyclotella sp.		6	
Diploneis sp.			3
Epithema sp.			1
Fragilaria sp.			13
Melosira sp.		6	29
Navicula sp.		28	14
Nitzschia longissima		124	166
Nitzschia sp.		11	10
Pleurosigma sp.		2	3
Rhizosolenia sp.		3	
Skeletonema sp.		3	
Thalassionema sp.		31	50
Total Dinoflagellates	727	46	37
Total Diatoms	11	416	384
Total count/100 ml	738	462	421

Table 13. OCCURRENCE OF PHYTOPLANKTON AT STATION 5

Phytoplankton	Surface	Mid-depth	Bottom
Dinoflagellates			
Amphidinium sp.	72	929	4
Ceratium fusus	25		5
Ceratium lineatum	1947	16	6
Ceratium longipes	1007	8	5
Dinophysis sp.	98	7	
Gymnodinium sp.	12	18	6
Peridinium sp.	72	30	27
Prorocentrum sp.	52	42	18
Diatoms			
Biddulphia sp.		1	4
Chaetoceros sp.	1	6	
Coscinodiscus sp.	19	35	38
Diploneis sp.		8	
Ditylum sp.			3
Melosira sp.		9	
Navicula sp.		10	5
Nitzschia longissima	1	73	
Nitzschia sp.		3	1
Pleurosigma sp.		2	
Rhizosolenia sp.	5	3	53
Thalassionema sp.		6	
Total Dinoflagellates	3285	1054	71
Total Diatoms	26	156	104
Total count/100 ml	3311	1210	175

Table 14. OCCURRENCE OF PHYTOPLANKTON AT STATION 9

Phytoplankton	Surface	Mid-depth	Bottom
Dinoflagellates			
Amphidinium sp.	109	1	26
Ceratium fusus	38	84	
Ceratium lineatum	2124	2338	
Ceratium longipes	698	330	
Dinophysis sp.	168	134	
Gymnodinium sp.	40	6	
Peridinium sp.	52	42	8
Prorocentrum sp.	67	40	4
Diatoms			
Biddulphia sp.	4	1	2
Chaetoceros sp.	24	60	6
Coscinodiscus sp.	14	30	28
Melosira sp.	2		12
Navicula sp.		4	30
Nitzschia longissima	2		
Nitzschia sp.			14
Pleurosigma sp.		2	6
Rhizosolenia sp.	43	10	
Skeletonema sp.	3	56	
Thalassionema sp.	1		50
Total Dinoflagellates	3296	2975	338
Total Diatoms	93	163	316
Total count/100 ml	3389	3138	354

Table 15. OCCURRENCE OF PHYTOPLANKTON AT STATION 14

Phytoplankton	Surface	Mid-depth	Bottom
Dinoflagellates			
Amphidinium sp.	47	40	14
Ceratium fusus	2	1	
Ceratium lineatum	5	23	
Ceratium longipes	294	112	6
Dinophysis sp.	9	2	
Gymnodinium sp.	2		
Peridinium sp.	5	7	12
Prorocentrum sp.	4	7	
Diatoms			
Biddulphia sp.	1	2	4
Chaetoceros sp.	27	27	12
Coscinodiscus sp.	88	86	502
Melosira sp.	6		16
Navicula sp.	4		14
Nitzschia longissima	2		26
Nitzschia sp.			34
Rhizosolenia sp.		45	
Thalassionema sp.		2	182
Total Dinoflagellates	366	194	32
Total Diatoms	128	162	608
Total count/100 ml	494	356	640

Table 16. OCCURRENCE OF PHYTOPLANKTON AT STATION 17

Phytoplankton	Surface	Mid-depth	Bottom
Dinoflagellates			
Amphidinium sp.		136	38
Ceratium fusus	50	54	
Ceratium lineatum	2854	3798	2
Ceratium longipes	1792	2632	1
Dinophysis sp.	206	244	
Gymnodinium sp.	10	66	13
Peridinium sp.	108	666	1
Prorocentrum sp.	70	42	8
Diatoms			
Chaetoceros sp.			2
Coscinodiscus sp.		12	26
Melosira sp.			19
Navicula sp.		2	104
Nitzschia longissima	4	2	521
Nitzschia sp.			57
Pleurosigma sp.			6
Rhizosolenia sp.	4	14	
Thalassionema sp.			38
Total Dinoflagellates	5090	7638	63
Total Diatoms	8	30	773
Total count/100 ml	5098	7668	836

Surface sample at all stations were completely dominated by dinoflagellates. *Ceratium* comprised the larger percent of the sample, with *Ceratium lineatum* and *Ceratium longipes* being the dominant species (Figures 19 and 20). Several species of *Dinophysis*, *Prorocentrum* and *Peridinium* were also found at each station with great regularity but were of secondary importance to *Ceratium* (Figures 21 and 22).

There was a marked difference between the surface samples, a dinoflagellate community, and the bottom samples which are made up, to a large extent, by diatoms. *Nitzschia longissima*, *Coscindiscus* sp., *Thalassionema* sp., and *Navicula* sp. were generally the most commonly found diatoms.

Several small differences were noted between stations, most of which can be explained by the location. Counts at Station 9 and Station 17, the two most inshore stations, were higher than at most other stations. This can be understood because, as a rule, inshore areas are more heavily populated. Counts on Station 14 and Station 2 were considerably lower than any other stations. Station 14 is the most offshore station and offshore areas are typified by decreasing numbers of dinoflagellates and a sparser standing crop. Station 2, however, was in the middle region in the center of the dumpsite area and would not fall into the same offshore category as Station 14. The reasons for the lower count at Station 2 are unknown. Some differences in phytoplankton populations can be attributed to natural patchiness found in transition areas.

In summary, the phytoplankton in this area, at this time of year, seemed to be as expected from previous published works. It was a healthy dinoflagellate-dominated community.

B. ZOOPLANKTON

1. Previous Work

Plankton investigations were conducted by Deevey (1960) for waters in the Delaware Bay and outlying coastal provinces. In general, maximal numbers

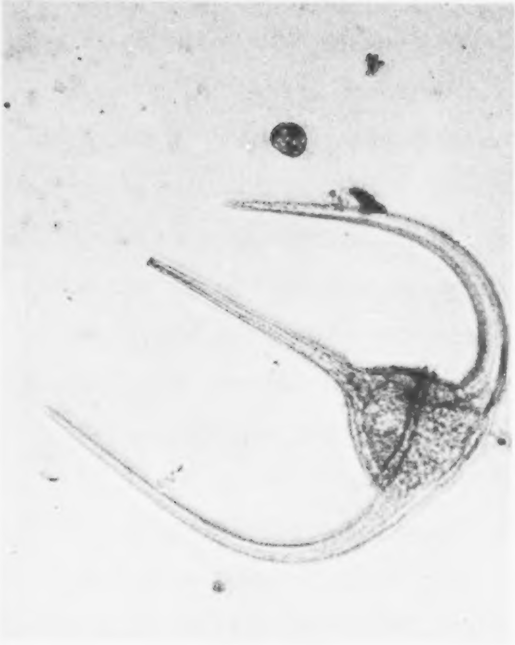


Figure 19 — Ceratium longipes, one of the dominant dinoflagellates at all stations.

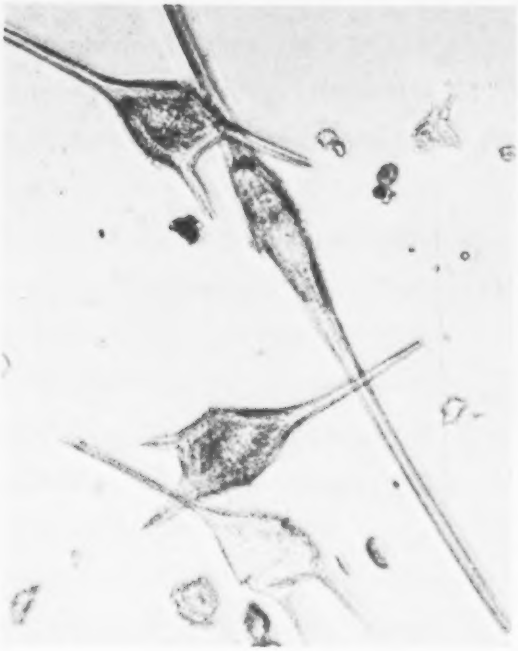


Figure 20 — Ceratium fusus (elongated cell at right) and three cells of Ceratium lineatum.

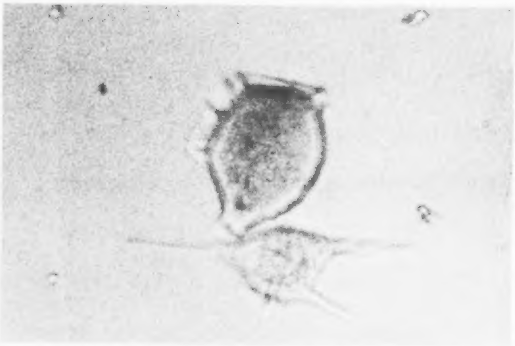


Figure 21 — Ceratium lineatum (below) and a species of Dinophysis (above). Both are dinoflagellate species.

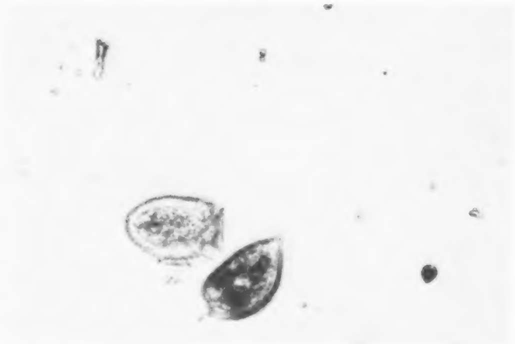


Figure 22 — Two species of dinoflagellates, Dinophysis (left) and Prorocentrum (right).

and volumes were recorded in summer and late fall and minimal numbers in late winter and spring. However, despite differences in seasonal cycles, the relative quantity of zooplankton varies similarly from year to year within the Bay and in outlying waters. Copepods are by far the most dominant group within the plankton community while Acartia tonsa dominates in the more offshore waters and Paracalanus parvus and Pseudocalanus minutus are the next most abundant species. Due to the wide annual temperature range (0 to 25°C) in these waters, few organisms occur throughout the year and only four copepods (Acartia tonsa, Pseudododiaptomus coronatus, Centropages typicus and Paracalanus parvus) are considered year-round species.

The University of Delaware (1972) in a zooplankton study for the Environmental Protection Agency showed copepods to dominate numerically and volumetrically. Copepod dominance occurred in the late fall and 32 species were recorded for the coastal waters slightly northwest of the present dumpsite. Also during the late fall, the greatest diversity of zooplankton was found which was coincident with the destruction of the thermocline. However, unlike Deevey, the Delaware report shows highest plankton volumes in spring and early summer.

2. Survey Cruise

A preliminary baseline plankton investigation was conducted at four of the stations (1, 2, 9 and 14; see Figure 3) within and near the site designated for the ocean dumping of sludge wastes. Four paired net hauls were taken: two within the proposed dumpsite, one nearer to shore, and one on the outside of the dumpsite offshore. The resultant information gathered during the investigation is presented as taxonomic relative percent composition and biomass measurements.

Zooplankton samples were collected from the four stations in an oblique fashion from the surface to near-bottom to surface for approximately 15 minutes duration. The paired samples consisted of two nets (Figure 23) of different mesh

Figure 23 — Paired plankton nets with 202 μ and 1,000 μ mesh used for oblique tows.

sizes, each measuring ½ meter by ½ meter and about 4 meters in length. Into the mouth opening of each net was placed a precalibrated T.S.K. type mechanical flowmeter to record the volume of water passing through each net. The mesh aperture for one of the nets was 1,000 μ while the second net was 202 μ. The collections from each of the nets during the four tows showed a definite catch selectivity regarding size and composition. One-third of the 202 μ samples and each of the 1,000 μ samples were preserved with 7% buffered formalin.

In the laboratory, the 202 μ net samples were fractioned in a Folsom splitter to an aliquot not less than 1/32 of the whole. The taxonomic analysis consisted of counting uniform percentages of these samples to the group level and identifying the major taxa present. These data are presented in Table 17.

Four parameters of biomass from the 202 μ net samples were measured: wet weight, displacement volume, dry weight, and total organic weight. Wet weights were determined by washing the sample matter into a precalibrated fritted glass Gooch crucible, applying slight air pressure to expel most of the interstitial water, and weighing the residue on an analytical balance. The Gooch crucible mercury immersion method described by Yentsch and Hebard (1957) was used for measurement of displacement volumes. Dry weights were determined according to procedures by Lovegrove (1966) by heating samples at 60°C for 2 hr in a vacuum oven. Organic weights were derived by igniting the dried samples in furnace at 450°C for 2 hr, cooling to room temperature, and weighing. The ashed value was then subtracted from the dried weight to reflect the combustible organic fraction. The resultant data for the 202 μ net biomass analysis are given in Table 18. The material collected from the 1,000 μ net was of sufficiently small quantity that total counts and average sizes could be measured (Table 19). No biomass analysis was performed on these samples.

Table 17. RELATIVE PERCENT COMPOSITION OF 202 μ NET ZOOPLANKTON

	Sampling Stations			
	Nearshore	Dumpsite		Offshore
Zooplankton	Day	Night	Day	Night
Copepoda	35.5	38.8	60.5	72.7
Dinoflagellata	40.8	30.6	13.8	7.9
Cladocera	17.3	23.8	19.6	2.3
Pteropoda	0.3	3.2	1.1	11.1
Larvacea	3.0	0.7	1.2	1.2
Chaetognatha	1.0	0.5	1.4	2.3
Medusae	1.0	1.0	1.6	—
Fish Eggs	1.0	0.2	0.3	1.1
Polychaeta	0.2	0.7	0.6	0.7
Bivalva	—	0.3	0.2	0.7
Fish Larvae	—	0.1	0.2	—
Trochophore	—	0.1	0.2	—
Euphausidacea	—	*	0.2	—
Brachyura	—	0.2	—	—
Foraminifera	—	—	—	0.2
Decapod Larvae	—	—	—	0.2
Sipunculids	0.2	—	—	—
Ostracoda	—	*	—	—
Echinoid Larvae	—	0.1	—	—
Unknowns	*	*	—	*

*Present

Table 18. ZOOPLANKTON BIOMASS OF 202 μ NET

Biomass	Sampling Stations Nearshore	 Dumpsite	 Offshore
Displacement vol. ($\mu l/m^3$)	201.44	240.30	224.18
Wet weight (mg/m^3)	177.14	199.74	108.84
Dry weight (mg/m^3)	19.76	13.78	27.08
Organic weight (mg/m^3)	16.94	12.63	24.37

3. Interpretation

Resultant plankton data from the 202 μ net tows do not show any clear differences between taxa or biomass concentrations at any of the four stations sampled. Comparative community correlation coefficients of taxa present show Stations 1 and 2 (within the proposed dumpsite) to have the greatest degree of community correlation: 0.764 on a scale where 0.500 is average and 1.000 the highest correlation possible. These two stations were also within the closest proximity with regard to all four stations. All stations recorded higher than 0.500 except Station 14 (0.450), indicating the basic plankton community structure at all stations to be generally the same. However, subtle differences can be seen as one moves from the nearshore station (9) toward the offshore stations (14). Figure 24 shows a plot of the relative percent compositions of the four most dominant planktonic groups present at all four stations with respect to position. Typically, the dinoflagellates and cladocera decrease and copepods increase toward dominance in the more neritic waters. Additionally, the numbers of copepod species increase as one moves from nearshore to offshore indicating a greater diversity of copepod species in the more neritic waters of the continental shelf.

Biomass measurements do not indicate any obvious differences among the four stations sampled. The highest plankton volume was recorded in the dumpsite

Table 19. PLANKTON TAXONOMY FROM 1,000 μ NET TOWS AT MACROPLANKTON SAMPLING STATIONS

Plankton	Nearshore		Dumpsite				Offshore	
	Station 9 Day		Station 1 Night		Station 2 Day		Station 14 Night	
	Number*	Size†	Number*	Size†	Number*	Size†	Number*	Size†
Fish Eggs - undeveloped	973.15	(1.30)	194.00	(1.30)	161.24	(1.30)	5.06	(1.34)
- developed	369.12	(1.26)	34.53	(1.26)	16.30	(1.26)	12.85	(1.22)
Decapoda-Caridea - large	—		—		—		1.16	(13.82)
Caridea - small	—		5.91	(6.24)	5.15	(5.11)	3.11	(8.37)
Caridea - larval	—		—		—		7.01	(4.40)
Penaeidea - large	—		1.36	(15.37)	—		1.56	(10.22)
Penaeidea - small	—		9.09	(9.07)	—		—	
Brachyura - larvae - larva	—		6.36	(1.20)	2.57	(9.00)	1.16	(4.71)
Amphipoda	—		0.45	(6.47)	—		1.56	(4.93)
Copepoda - Centropages typicus	—		—		—		0.78	(2.05)
- Eucalanus elongatus	—		—		—		1.16	(4.42)
Other Crustacea	—		0.91	(4.50)	—		—	
Chaetognatha - Sagitta	—		—		—		1.16	(13.58)
Anthomedusae	—		—		—		0.39	(2.45)
Ctenophora	—		—		18.87	(11.95)	—	
Fish Larvae	—		0.45	(6.47)	—		—	

*Number of organisms times $10^{-2}/m^3$ seawater

†Avg. size of organisms in mm

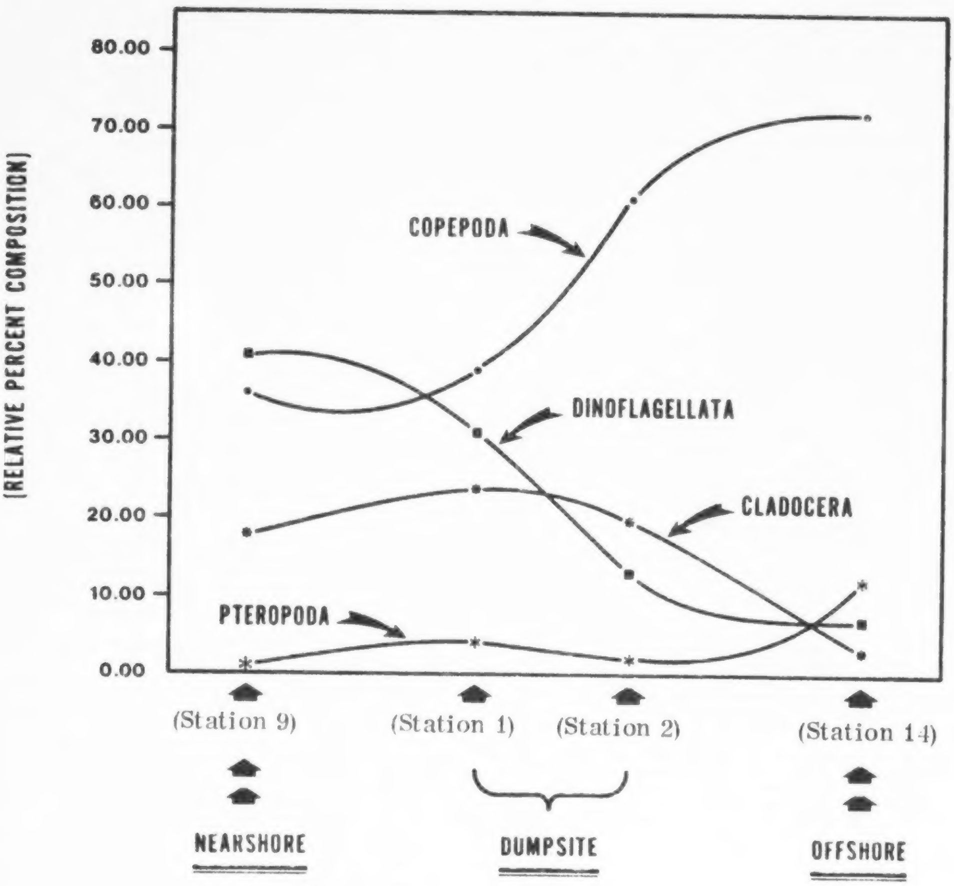


Figure 24 — 202 μ net plankton relative percent composition plotted from nearshore station through the proposed dumpsite to the most offshore station.

(Station 2) while the highest wet weight was found at Station 14, farthest offshore. Yet the dumpsite recorded the lowest total dry and organic weights of the stations sampled. However, the differences between any of the four stations measured were quite negligible compared to the different biomass values expected from nonrandom distributions, patchiness, and seasonal fluctuations in standing stock. None of the values recorded for any of the four parameters measured were more or less than 33% of the mean value for the stations sampled. Table 20 shows the biomass ratios obtained by other investigators as well as the ratios from the present investigation.

Table 20. BIOMASS RATIOS OF ZOOPLANKTON ACCORDING TO VARIOUS INVESTIGATIONS

Displacement Vol., $\mu l/m^3$	Wet Wt., mg/m^3	Dry Wt., mg/m^3	Total Organic Wt., mg/m^3	Investigator
12.4	9.0	1.0	1.0	Present investigation
15.9	13.0	1.1	1.0	Bé, et al., 1971
10	10	1.0	—	Hopkins, in press
—	—	1.25	1.0	Beers, 1966
26.5	—	1.0	—	Bsharsh, 1957
18.0	—	1.4	1.0	Menzel and Ryther, 1961

The information gathered from the 1,000 μ net tows indicates definite catch selectivity of the samples. No large decapods were taken from the 202 μ nets while the 1,000 μ net easily collected these shrimp-like forms. The results shown in Table 19 indicate a reasonable correlation between the day and night hauls. It seems apparent that the decapods and other large crustacea are absent from the water column during the daytime and migrate to the surface waters at night. This would indicate that these forms are associated with the bottom waters and may play an important role in epibenthonic trophic dynamics.

The basic conclusions from such a limited effort seem to indicate that the plankton populations within the proposed dumpsite are typical of temperate coastal waters. Differences in species composition from the nearshore station to the most offshore station suggests that the proposed dumpsite lies within the transitional waters of the coastal neritic province influenced by both nearshore waters and oceanic waters.

C. VERTEBRATES

1. Previous Work

Vertebrate studies in the immediate area of the survey cruise were reported by the University of Delaware, College of Marine Studies (1972). This study and a paper by Clark et al. (1969) are in general agreement.

2. Survey Cruise

There are two major parts to this section — the first deals with the analysis of the vertebrates collected at Station 2 in a 16 ft otter trawl and the second with the videotape observations of the bottom at the proposed dumpsite.

a. Collected Vertebrates —

The otter trawl was deployed once, at 11 am on 2 May 1973. The location fished was 38°22.3' N, 74°14.2' W, which had been designated Station Number 2, at the middle of the projected dump area. A number of other types of samples were collected and video recordings were made at this station. The trawl was fished for about 20 minutes at a depth of 44.6 meters. Evidence that the trawl was in fact a bottom trawl was provided by a number of sand dollars found in the net with the fishes.

The entire catch (unsorted) was preserved in 10% formalin for later analysis. Upon arrival at Millersville, fishes were identified to species, measured (standard length), and dissected to determine sex, reproductive state, and stomach contents. In addition, fishes were examined for external parasites and gut parasites. Small sample size precludes statistical analysis; however, qualitative information can be provided.

b. Video Recorded Observations —

The bottom was of three types.

The first type was irregularly grooved with pronounced "hills and valleys," resembling a slope subject to erosion. In the deeper portions of the valleys there could be seen dark, flaky material which was stirred up when the camera bumped the bottom (the sand forming the irregular substrate was not stirred up by this bumping). A few sand dollars (probably Echinarachnius) could be seen as well as shells of the pelecypod molluscs Spisula solidissima and Tagelus plebeius (surf clam and stout razor clam), a hermit crab and a goosefish, probably Lophius americanus (Cuvier). Also seen was a skate, probably genus Raja but too indistinct to be more precise. The television camera was moving rapidly because of wave action during this sequence but it looked as though there might be worm burrows or molusc siphon holes in the sandy areas of the bottom. This bottom type appeared most normal of the three types and seemed to support the greatest species diversity.

The second type of bottom was more heavily overlain by dark, flaky material so that only occasional patches of clear sand could be seen. Here were seen more empty bivalve shells and two sea robins, probably Prionotus carolinus (Linnaeus) and one skate (Raja). Sand dollars and starfish (probably Asterias) were more abundant and in one area numbers of sea urchins were seen.

The third type of bottom was completely covered by the dark material. Empty and broken bivalve shells were scattered about and the greatest density of sand dollars was seen on the surface. Starfish were also more abundant.

The dark material was again seen to be flaky when stirred by the bumping of the camera rig on the bottom. With the exception of one unidentifiable fish which passed close to the camera, well off the bottom, no fishes were seen over this type of bottom.

The videotapes were most interesting and definitely should be a part of any future visits to the site. The samples (including cores) provide instantaneous single location information about the bottom. These should be combined with horizontal visual sampling of the bottom (U. T. V.) which helps place the bottom samples into perspective vis-a-vis the area of bottom such a sample represents.

3. Interpretation

The catch included 14 common sea robins, *Prionotus carolinus* (Linnaeus) which ranged in size from 160 to 230 mm, standard length. Also collected were three mud hake, *Urophycis tenuis* (Mitchill) (270 to 300 mm standard length), one rusty dab, *Limanda ferruginea* (Storer) of 280 mm standard length, and two ocean pout, *Macrozoarces americanus* (Bloch and Schneider) of 330 mm and 145 mm standard length (Table 21).

It is reported by Bigelow and Schroeder (1953) that *Prionatus carolinus* reaches a length of 380 mm, so it seems likely that though most (8) appeared to be sexually mature they probably had not yet achieved full adult size. There is no sexual dimorphism in this species. The same authors report a maximum size of 120 cm for the *Urophycis tenuis*; however, they cite the most common size caught in trawls as 70 cm. Thus it appears the three mud hake are less than half the average adult size. The average size of male *Limanda ferruginea* was reported as 394 mm, so the individual here reported is approaching adult size.

Stomachs of all sea robins contained recognizable remains of shrimps (eyes and antennae, appendages) in various stages of digestion but none of them

Table 21. VERTEBRATES COLLECTED

	Species	Std. length, mm	Gonad
1.	*Prionotus carolinus* (Linnaeus)	195	mature male
2.	same	160	mature female
3.	same	165	mature female
4.	same	195	mature female
5.	same	164	immature male
6.	same	172	immature female
7.	same	160	immature female
8.	same	197	mature female
9.	same	178	mature female
10.	same	176	mature female
11.	same	180	mature female
12.	same	138	immature male
13.	same	230	female
14.	same	188	
15.	*Limanda ferruginea* (Storer)	280	mature male
16.	*Urophycis tenuis* (Mitchill)	270	mature male
17.	same	300	mature male
18.	same	285	mature male
19.	*Macrozoarces americanus*	330	female
20.	same	145	juvenile

recent enough to indicate feeding while in the trawl net. Stomachs of mud hake contained, in addition to shrimp remains, numerous fragments of crab carapace. The rusty dab contained shrimp and crab remains and fragments of mollusc shell, apparently that of a pelecypod. The stomach of the large ocean pout contained remains of shrimp, large sections of crab carapace and appendages, and several small sand dollars.

Parasites were not seen on or in any of the sea robins or the dab, but were seen in the gut of two of the mud hake, fishes number 14 and 15. All fishes appeared healthy and were relatively undamaged by the trawl net.

Bigelow and Schroeder provide considerable information on the biology, systematics, and life history of the three species collected. All are bottom feeders which typically are found in the 20 to 40 fathom depths although the sea robin is also found to 90 fathoms.

All three species collected on this cruise were mentioned by Clark et al. (1969), which provided full sampling information and also data on salinity (surface and depths to 40 meters) and temperature (surface and bottom isotherm and horizontal profile to 100 meters).

Although migration of sea robins is described by Bigelow and Schroeder, the movements are onshore and offshore in response to the cooling of inshore water, rather than alongshore. All three species live near the bottom and are carnivores feeding on invertebrates which live on or in the sediments. These fish species might be utilized as indicator species in cases where benthic pollution or accumulation of heavy metals or radionuclides is of interest.

D. BENTHIC ORGANISMS

1. Previous Work

Previous research in benthic ecology encompassing the area from southern New Jersey to the northern part of the Delmarva Peninsula was summarized in a report on the probable effects of a deepwater oil terminal

(Maurer and Wang, 1973). This report included research conducted three miles east of Great Bay, New Jersey (Raney et al., 1972), Cape Henlopen near the mouth of Delaware Bay (Maurer et al., 1973), approximately 14 miles southeast of the mouth of Delaware Bay (Maurer, unpublished data), and an acid dumpsite approximately 38 nautical miles southeast of Cape Henlopen (du Pont et al., 1972).

Research at the New Jersey site is still in progress but a preliminary checklist of invertebrates was presented by Raney et al. (1972). In general, the fauna consisted mainly of suspension feeders (surf clam, bay scallop) and epifaunal (rock barnacle, hydroids), and vagile (lady crab, blue crab) species commonly associated with a clean sand bottom and/or a hard substrate.

Near the mouth of Delaware Bay, 115 species were collected (Maurer et al., 1973). The bivalves, *Nucula proxima* and *Tellina agilis* were the dominant species throughout the area and represented mud (<0.063 mm) and sand (>0.063 to 0.50 mm) bottom communities respectively. These communities contained a greater number of deposit feeders than the New Jersey situation, but this varied with the amount of fine sediment present.

At the former sludge disposal site, approximately 14 miles southeast of Delaware Bay, a preliminary survey revealed a diverse and interesting mixture of epifaunal and infaunal species (Maurer, unpublished data). Depending on sediment type, and to some extent water depth, the fauna was dominated by infaunal deposit feeders, *Nucula proxima*, *Yoldia limatula*, *Tellina agilis*; infaunal suspension feeders, *Ensis directus*, *Arctica islandica*; and a variety of epifaunal species, *Obelia longissima*, *Sertularia argentea*, *Electra hastingsae*, etc. Huge numbers (12,000 to 15,000/0.1 m^2) of *Nucula proxima* were found in organic muds. Even though *N. proxima* is normally a deposit feeder associated with fine sand and organic muds, the large numbers of bivalves are suggestive of an enriched environment.

At the acid waste site, research is still in progress, but a preliminary description of benthos is contained in du Pont et al. (1972). The general character of the stations was considered similar. Stations were dominated by the sand dollar, *Echinarachnius parma*, the sand shrimp, *Crangon septemspinosa*, and by a small ascidean, *Bostrichobranchus pilularis*. Other common invertebrates were the sea stars, *Asterias forbesi* and *A. vulgaris*, bivalves, *Cardita borealis* and *Arctica islandica*, rock crab, *Cancer irroratus*, and the hermit crab, *Pagurus annulipes*.

2. Survey Cruise

For the purpose of this survey, samples collected aboard the R/V ANNANDALE and maintained in a cold room, were transferred to 10% buffered formalin. Specimens from 49 samples distributed among nine stations were carefully picked and sorted into jars labeled mollusca, arthropoda, annelida, and miscellaneous. These specimens were then identified under microscope using a variety of literature sources summarized in Maurer and Watling (1973a,) Maurer and Wang (1973b), and Watling and Maurer (1973) and local reference collections which have been confirmed by specialists for some taxonomic groups (amphipods, isopods, hydroids). Specimens were identified to species wherever possible and counts were made. In addition to the quantitative samples, invertebrates collected with an otter trawl were also examined and identified. Size measurements of starfish (central disc to tip of arm) and sand dollars (greatest and least diameter) were taken to provide supplementary information. A species list was prepared (Table 22) and the species and counts were tabulated in preparation for future analysis (Tables 23 through 31). Size distributions of echinoderm measurements were also made (Table 32). Size frequency distributions of *Echinarachnius parma* are shown in Figures 25, 26, and 27.

Benthic macroinvertebrates were also sampled with an anchor dredge and separated from the sediments with a 2 mm mesh screen. Subsequently, the sand dollar *Echinarachnius parma*, being the most numerous and present in each sample, was subjected to heavy metal and pesticide analyses (see Section E). Other macroinvertebrates collected by this means are shown in Table 33.

Table 22. SPECIES LIST OF BENTHIC INVERTEBRATES

- Phylum Cnidaria
    - Class Hydrozoa
        - Order Hydroida
            - Suborder Athecata
                - Family Eudendridae
                    - *Eudendrium dispar*(Agassiz, 1862)
            - Suborder Thecata
                - Family Campanularidae
                    - *Campanularia neglecta* (Alder, 1857)
                - Family Sertulariidae
                    - *Sertularia argentea*(Linné, 1758)

- Phylum Rhynchocoela
    - Nemertean sp. 1
    - Nemertean sp. 2

- Phylum Annelida
    - Class Polychaeta
        - Family Cirratulidae
            - *Tharyx marioni* (Saint-Joseph, 1894)
            - *Chaetozone* sp.
            - Cirratulidae sp.

        - Family Dorvilleidae
            - *Stauronereis rudolphi* (Delle Chiaje, 1828)
            - *S. caecus* (Webster and Benedict, 1884)

        - Family Eunicidae
            - *Marphysa bellii* (Audouin and Milne-Edwards, 1833)
            - *Eunice pennata* (O.F. Muller, 1776)

        - Family Glyceridae
            - *Glycera dibranchiata*(Ehlers, 1868)

        - Family Goniadidae
            - *Progoniada regularis*(Hartman, 1965)

        - Family Lumbrinereidae
            - *Lumbrinereis acuta* (Verrill, 1875)
            - *L. brevipes* (McIntosh, 1903)
            - *L. paradoxa*(Saint-Joseph, 1888)

        - Family Maldanidae
            - *Clymenella torquata* (Leidy, 1855)
            - *Axiothella mucosa* (Andrews, 1891)

        - Family Nephtyidae
            - *Aglaophamus circinata* (Verrill, 1874)
            - *Nephtys picta*(Ehlers. 1868)
            - Nephtyidae sp. 1

Table 22. (Continued)

- Family Nereidae
  - *Ceratocephale loveni*(Malmgren, 1867)

- Family Paraonidae
  - *Aricidea jeffreysi* (McIntosh, 1879)
  - *A. suecica*(Eliason, 1920)
  - *A. wassi*(Pettibone, 1965)
  - Paraonidae sp.

- Family Phyllodocidae
  - *Eteone lactea*(Claparède, 1868)
  - *E. trilineata*(Webster and Benedict, 1887)
  - *E. longa* (Fabricius, 1780)
  - *E. flava* (Fabricius, 1780)
  - *Phyllodoce* *(Anaitides)* *maculatus* (Linné, 1767)

- Family Sabellidae
  - *Sabella microphthalma* (Verrill, 1873)
  - *Euchone* sp.

- Family Sigalionidae
  - *Sigalion arenicola*(Verrill, 1879)
  - *Sthenelais limicola* (Ehlers, 1864)

- Family Spionidae
  - *Spiophanes bombyx* (Claparède, 1870)
  - *Scolecolepides viridis* (Verrill, 1873)

- Family Syllidae
  - *Syllis gracilis* (Grube, 1840)
  - *S. cornuta* (Rathke, 1843)
  - *Exogone verugera* (Claparède, 1868)
  - *Brania wellfleetensis*(Pettibone, 1956)
  - *Autolytus cornutus*(Agassiz, 1863)

- Family Terebellidae
  - Terebellidae sp.

- Incertae sedis
  - Unknown sp. 1

- Phylum Mollusca
  - Class Gastropoda
    - Subclass Prosobranchia
      - Order Archaeogastropoda
        - Family Trochidae
          - *Margarites groenlandicus* Gmelin

      - Order Mesogastropoda
        - Family Caecidae
          - *Caecum cooperi* S. Smith

Table 22. (Continued)

Family Calyptraeidae
Crepidula plana (Say, 1822)
C. fornicata (Linné, 1758)

Family Naticidae
Polinices duplicatus (Say, 1822)
P. immaculatus Totten
Natica canrena Linné
Natica sp.

Order Neogastropoda
Family Buccinidae
Colus pygmaea (Gould, 1841)

Family Melongenidae
Busycon canaliculatum (Linné, 1758)

Family Nassariidae
Nassarius trivittatus (Say, 1822)

Family Turridae
Mangelia cerina (Kurtz and Stimpson, 1851)

Subclass Opisthobranchia
Order Tectibranchia
Family Acteonidae
Acteon sp.

Family Pyramidellidae
Turbonilla interrupta (Totten, 1835)

Class Pelecypoda
Order Protobranchia
Family Nuculidae
Nucula proxima (Say, 1820)

Order Filibranchia
Family Arcidae
Anadara transversa (Say, 1822)

Family Mytilidae
Crenella glandula Totten
Mytilus edulis (Linné, 1758)

Family Pectinidae
Placopecten magellanicus Gmelin

Family Anomiidae
Anomia simplex (Orbigny, 1895)

Table 22. (Continued)

Family Ostreidae
Crassostrea virginica (Gmelin, 1792)

Order Eulamellibranchia
Family Astartidae
Astarte undata (Gould, 1841)
A. castanea Say
A. subequilatera Sowerby

Family Carditidae
Venericardia borealis (Conrad, 1831)

Family Arcticidae
Arctica islandica Linné

Family Lucinidae
Phacoides filosus Stimpson

Family Cardiidae
Cerastoderma pinnulatum Conrad
Trachycardium muricatum Linné

Family Veneridae
Pitar morrhuana (Linsley, 1845)
Transenella stimpsoni Dall
Dosinia discus Reeve

Family Tellinidae
Tellina agilis (Stimpson, 1858)

Family Semelidae
Abra lioica Dall

Family Solenidae
Ensis directus (Conrad, 1843)

Family Mactridae
Spisula solidissima (Dillwyn, 1877)

Family Corbulidae
Corbula contracta (Say, 1822)

Family Pandoridae
Pandora gouldiana (Dall, 1866)
P. trilineata Say

Phylum Arthropoda
Class Crustacea
Subclass Malacostraca

Table 22. (Continued)

- Order Cumacea
  - Family Leuconidae
    - *Eudorella* sp. 1
  - Family Diastylidae
    - *Diastylis* sp. 1
  - Family Unknown
    - Unidentified sp. 1

- Order Tanaidacea
  - Family Paratanaidae
    - *Leptochelia* sp. 1

- Order Isopoda
  - Suborder Flabellifera
    - Family Cirolanidae
      - *Cirolana concharum* (Stimpson, 1853)
      - *C. impressa*(Harger, 1883)
      - *C. polita* (Stimpson, 1853)
  - Suborder Valvifera
    - Family Idoteidae
      - *Chiridotea arenicola*(Wigley, 1960)
      - *C. stenops*(Menzies and Frankenberg, 1966)
      - *Edotea triloba* (Say, 1818)

- Order Amphipoda
  - Suborder Gammaridea
    - Family Ampeliscidae
      - *Ampelisca vadorum*(Mills, 1963)
      - *A. declivitatus*(Mills, 1967)
      - *Byblis serrata*(Smith, 1874)
    - Family Calliopiidae
      - *Apherusa gracilis*(Holmes, 1905)
    - Family Corophiidae
      - *Siphonoecetes smithianus*(Rathbun, 1905)
      - *Unciola dissimilis*(Shoemaker, 1945)
      - *U. inermis*(Shoemaker, 1945)
      - *U. irrorata*(Say, 1818)
    - Family Haustoriidae
      - *Protohaustorius deichmannae*(Bousfield, 1965)
      - *P. wigleyi*(Bousfield, 1965)
    - Family Lyssianassidae
      - *Hippomedon serratus*(Holmes, 1905)
    - Family Phoxocephalidae
      - *Trichophoxus epistomus* (Shoemaker, 1938)
      - *Paraphoxus spinosus*(Holmes, 1903)
      - *Phoxocephalus holbolli* (Kroyer, 1842)
    - Family Stenothoidae
      - *Proboloides holmesi* (Bousfield, 1973)
  - Suborder Caprellidea
    - Family Caprellidae
      - *Aeginina longicornis* (Kroyer, 1842)

Table 22. (Continued)

- Phylum Ectoprocta
  - Class Gymnolaemata
    - Order Ctenostomata
      - Family Alcyonidiidae
        - *Alcyonidium polyoum* (Hassall, 1841)
      - Family Flustrellidae
        - *Flustrellidra hispida* (Fabricius, 1780)
    - Order Cheilostomata
      - Suborder Anasca
        - Family Alderinidae
          - *Callopora* sp.
        - Family Scrupariidae
          - *Scruparia chelata* (Linne, 1758)
      - Suborder Ascophora
        - Family Microporellidae
          - *Microporella ciliata* (Pallas, 1766)
        - Family Smittinidae
          - *Parasmittina* sp.

- Phylum Echinodermata
  - Class Echinoidea
    - Family Arbaciidae
      - *Arbacia punctulata* (Lamarck, 1816)
    - Family Echinarachnidae
      - *Echinarachnius parma* (Lamarck, 1816)
  - Class Ophiuroidea
    - Ophiuroid sp. 1

- Phylum Chordata
  - Subphylum Urochordata
    - Class Ascidiacea
      - Ascidian sp. 1

Table 23. OCCURRENCE OF BENTHIC INVERTEBRATES AT STATION 1

Species	Sample								
	01	02	03	04	05	06	07	08	09
Polychaeta									
Lumbrinereis paradoxa	1	5	3	2	6	3	1	13	3
Progoniada regularis	-	17	1	16	25	22	-	12	3
Tharyx sp.	-	1	-	-	-	-	-	-	-
Ceratocephale loveni	-	1	-	-	-	-	-	-	-
Axiothella mucosa	-	-	-	1	6	1	-	1	1
Paraonidae sp.	-	-	-	1	-	-	-	-	-
Chaetozone sp.	-	-	-	2	2	-	-	-	-
Aricidea suecica	-	-	-	-	1	3	-	-	-
Cirratulidae sp.	-	-	-	-	-	-	1	1	-
Ampharetidae sp.	-	-	-	-	-	-	-	2	-
Aglaophamus circinata	-	-	-	-	-	-	-	1	-
Nephtyidae sp.	-	-	-	-	-	-	-	-	2
Mollusca *									
Spisula solidissima	V	V	V	-	V	V	-	-	V
Venericardia borealis	V	V	V	V	V	V	V	V	V
Placopecten magellanicus	V	V	V	V	V	V	V	V	-
Cerastoderma pinnulatum	V	V	V	D	D	V	V	D	-
Astarte undata	V	V	-	-	-	-	-	-	-
Crepidula plana	D	D	-	-	D	-	D	-	D
Margarites groelandicus	1	-	V	-	-	V	-	-	-
Acteon sp.	D	-	-	-	-	-	-	-	-
Ensis directus	-	V	D	-	V	V	-	V	V
Nucula proxima	-	V	V	-	V	V	-	V	-
Anomia simplex	-	V	V	-	V	V	-	V	-
Crepidula fornicata	-	V	-	-	D	-	-	-	-
Transenella stimpsoni	-	-	V	V	-	V	-	-	V
Astarte castanea	-	-	-	D	V	D	V	V	V

* D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 23. (Continued)

Species	Sample 01	02	03	04	05	06	07	08	09
Mollusca (cont.)									
Tellina sp.	-	-	-	V	-	-	-	-	-
Nassarius trivittatus	-	-	-	-	D	D	-	-	-
Busycon canaliculatum	-	-	-	-	D	-	-	-	-
Anadara transversa	-	-	-	-	V	-	-	-	-
Crassostrea virginica	-	-	-	-	-	-	V	-	-
Mytilus edulis	-	-	-	-	-	-	-	V	-
Trachycardium muricatum	-	-	-	-	-	-	-	V	-
Polinices duplicatus	-	-	-	-	-	-	-	-	D
Crustacea									
Photohaustorius deichmannae	6	-	2	3	-	1	3	-	-
Trichophoxus epistomus	5	3	9	1	4	1	8	4	2
Cirolana concharum	2	1	-	-	-	-	-	-	-
Byblis serrata	1	-	1	-	-	-	3	-	-
Siphonoecetes smithianus	1	-	-	-	-	-	-	-	-
Chiridotea stenops	-	1	-	-	-	-	-	-	-
Cirolana polita	-	-	1	-	2	-	1	1	-
Hippomedon serratus	-	-	-	-	1	-	-	-	-
Unciola inermis	-	-	-	-	-	-	1	-	-
Phoxocephalus holbolli	-	-	-	-	-	-	-	1	-
Ampelisca declivitatus	-	-	-	-	-	-	1	-	-
Unciola irrorata	-	-	-	-	-	-	2	-	-
Others									
Echinarachnius parma	-	1	3	-	-	-	6	-	2
Obelia sp.	-	-	P	-	-	-	-	-	-
Microporella ciliata	-	-	P	-	-	-	-	-	-
Eudendrium dispar	-	-	-	P	-	-	-	-	-
Sertularia argentae	-	-	-	-	-	-	-	P	-
Ophiuroid sp.	-	-	-	-	-	-	-	1	-

Table 24. OCCURRENCE OF BENTHIC INVERTEBRATES AT STATION 2

	Sample				
Species	11	12	13	14	15
Polychaeta					
Aglaophamus circinata	2	-	-	-	-
Axiothella mucosa	-	2	2	-	1
Progoniada regularis	-	-	1	1	-
Nephtyidae sp.	-	-	-	1	1
Lumbrinereis paradoxa	-	-	-	2	-
Unknown sp. #1	-	-	-	1	-
Unknown sp. #2	-	-	-	-	1
Mollusca*					
Cerastoderma pinnulatum	V	-	V	-	-
Mytilus edulis	-	V	-	-	-
Venericardia borealis	-	V	V	V	V
Phacoides filosus	-	V	-	-	-
Transenella stimpsoni	-	V	-	-	V
Astarte undata	-	V	V	V	V
Colus pygmaea	-	1	-	2	-
Arctica islandica	-	-	V	-	V
Polinices immaculatus	-	-	1	-	-
Margarites groenlandicus	-	-	V	-	-
Ensis directus	-	-	-	1	-
Nucula proxima	-	-	-	1	-
Mangelia cerina	-	-	-	V	-
Astarte subequilatera	-	-	-	-	V
Natica canrena	-	-	-	-	1
Crustacea					
Cirolana concharum	4	-	-	-	-
Trichophoxus epistomus	-	2	2	1	2
Paraphoxus spinosus	-	-	1	-	-
Ampeliscidea sp.	-	-	1	1	-

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*D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 24. (Continued)

Species	Sample 11	12	13	14	15
Crustacea (cont.)					
Cumacea sp.	-	-	-	1	-
Cirolana impressa	-	-	-	-	1
Protohaustorius deichmannae	-	-	-	-	2
Cirolana polita	-	-	-	-	1
Others					
Echinarachnius parma	-	4	6	3	2
Callopora sp.	-	-	-	P	-
Aiscidian sp.	-	-	-	P	-
Nemertean sp.	-	-	-	-	1

Table 25. OCCURRENCE OF BENTHIC INVERTEBRATES AT STATION 5

	Sample				
Species	38	39	40	41	42
Polychaeta					
Progoniada regularis	1	2	10	9	5
Paraonidae sp.	1	-	-	-	-
Lumbrinereis acuta	-	1	2	6	-
Aricidea suecica	-	-	-	-	2
Chaetozone sp.	-	-	-	1	-
Axiothella mucosa	-	-	-	7	-
Mollusca *					
Ensis directus	V	-	-	-	-
Spisula solidissima	V	V	V	V	V
Venericardia borealis	V	V	-	V	V
Placopecten magellanicus	V	V	V	V	V
Cerastoderma pinnalutum	D	-	-	V	D
Arctica islandica	2	-	-	-	-
Tellina agilis	-	V	-	-	-
Crepidula plana	-	D	-	-	-
Anomia simplex	-	-	V	V	-
Astarte undata	-	-	V	-	-
Astarte castanea	-	-	1	1	V
Crenella glandula	-	-	-	-	V
Trachycardium muricatum	-	-	-	D	-
Colus pygmaea	-	-	-	D	-
Crustacea					
Cirolana polita	-	-	3	-	-
Edotea triloba	-	-	1	-	-
Unciola inermis	-	-	1	1	-
Unciola irrorata	-	-	3	-	-
Phoxocephalus holbolli	-	-	-	1	-

*D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 25. (Continued)

Species	Sample 38	39	40	41	42
Crustacea (cont.)					
Leptochelia sp.	-	-	-	1	-
Others					
Echinarachnius parma	-	-	1	-	-
Microporella ciliata	-	-	-	-	P
Nemertean sp. #1	-	-	-	11	4

Table 26. OCCURRENCE OF BENTHIC INVERTEBRATES AT STATION 8

	Sample				
Species	43	44	45	46	47
Polychaeta					
Progoniada regularis	3	7	7	4	22
Axiothella mucosa	1	2	3	-	11
Lumbrinereis acuta	1	8	3	3	4
Aglaophamus circinata	-	1	-	-	-
Unknown sp.	-	1	-	-	-
Stauronereis rudolphi	-	-	1	1	2
Brania wellfleetensis	-	-	-	1	-
Glycera dibranchiata	-	-	-	-	1
Aricidea suecica	-	-	-	-	4
Tharyx marioni	-	-	-	-	1
Stauronereis caeca	-	-	1	-	-
Nephtys picta	-	-	2	-	-
Mollusca*					
Anomia simplex	-	-	V	-	V
Spisula solidissima	-	V	V	-	V
Venericardia borealis	V	V	V	-	V
Astarte castanea	-	V	D	V	-
Placopecten magellanicus	V	V	V	V	V
Cerastoderma pinnulatum	1	V	D	D	D
Nassarius trivittatus	D	D	-	-	-
Crenella glandula	V	V	V	-	V
Crepidula plana	-	D	-	-	-
Tellina agilis	-	V	1	1	-
Arctica islandica	-	V	-	-	-
Natica sp.	-	1	-	-	-
Transenella stimpsoni	-	V	-	-	V
Dosinia discus	-	V	-	-	-
Ensis directus	-	-	V	D	V

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*D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 26. (Continued)

	Sample				
Species	43	44	45	46	47
Mollusca (cont.)					
Nucula proxima	-	-	V	-	-
Margarites greonlandicus	-	-	-	D	-
Crustacea					
Unciola inermis	-	-	1	1	-
Pnoxocephalus holbolli	2	-	-	-	-
Leptochelia sp.	-	1	-	-	-
Diastylis sp.	1	-	-	-	-
Unciola dissimilis	3	-	-	-	-
Cirolana polita	-	1	2	-	-
Unciola irrorata	-	2	1	2	-
Trichophoxus epistomus	-	1	-	1	1
Ampelisca vadorum	-	-	-	-	1
Others					
Nemertean sp. #1	-	4	-	7	-
Echinarachnius parma	-	3	-	-	-
Sertularia argentea	P	-	-	-	-
Flustrellidra hispida	P	-	-	-	-
Oligochaete sp. #1	-	1	-	-	-
Unidentified segmented object	-	-	-	1	-

Table 27. OCCURRENCE OF BENTHIC INVERTEBRATES AT STATION 9

Species	Sample				
	48	49	50	51	52
Polychaeta					
Sigalion arenicola	1	1	-	-	-
Progoniada regularis	4	-	-	-	-
Lumbrinereis acuta	1	-	8	-	2
Axiothella mucosa	1	-	-	2	1
Aricidea suecica	-	1	-	-	-
Nephtys picta	-	-	-	1	-
Sthenelais limicola	-	-	-	1	-
Autolytus cornutus	-	-	-	-	7
Mollusca*					
Ensis directus	V	V	-	-	-
Anomia simplex	V	-	V	-	-
Pandora trilineata	V	-	-	-	-
Venericardia borealis	V	V	V	-	V
Cerastoderma pinnulatum	V	V	D	-	D
Transenella stimpsoni	V	-	-	-	-
Astarte castanea	V	V	V	-	V
Tellina agilis	V	-	-	-	V
Turbonilla interuppta	D	-	-	-	-
Phacoides filosus	-	V	-	-	-
Pitar morrhuana	-	V	-	-	-
Crenella glandula	-	V	-	-	-
Placopecten magellanicus	-	V	-	-	V
Margarites groenlandicus	-	-	D	-	-
Polnices immaculatus	-	-	1	-	-
Spisula solidissima	-	-	V	V	-
Crepidula plana	-	-	D	-	-
	-	-	-	V	-
Nassarius trivittatus	-	-	-	1	D

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* D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 27. (Continued)

Species	Sample 48	 49	 50	 51	 52
Crustacea					
Chiridotea stenops	1	-	-	1	-
Protohaustorius wigleyi	1	3	-		
Trichophoxus epistomus	3	2	2	-	2
Cirolana concharum	2	-	-	-	-
Cirolana polita	-	-	-	1	-
Cancer irroratus	-	-	-	-	2
Chiridotea arenicola	-	-	-	-	1
Aeginina longicornis	-	-	-	-	1
Ampelisca declivitatus	-	-	-	-	1
Ampherusa gracilis	-	-	-	-	1
Proboloides holmesi	-	-	-	-	1
Others					
Echinarachnius parma	2	-	-	-	-
Sertularia argentea	-	-	-	-	P
Scruparia chelata	-	-	-	-	P
Campanularia neglecta	-	-	-	-	P
Eudendrium dispar	-	-	-	-	P

Table 28. OCCURRENCE OF BENTHIC INVERTEBRATES AT STATION 11

Species	Sample 16	17	18	19	20
Polychaeta					
Progoniada regularis	17	33	103	14	23
Lumbrinereis paradoxa	7	8	37	11	8
Syllis gracilis	2	-	-	-	-
Terebellidae sp.	1	-	-	-	-
Cirratulidae sp.	-	1	-	-	-
Glyceradibranchiata	-	-	1	1	1
Axiothella mucosa	-	-	6	2	-
Aricidea suecica	-	-	4	-	-
Syllis cornuta	-	-	2	-	2
Mollusca*					
Astarte castanea	V	V	V	V	V
Venericardia borealis	V	-	V	V	-
Ensis directus	V	-	-	-	-
Placopecten magellanicus	V	-	V	V	V
Crenella glandula	V	-	-	-	V
Colus pygmaea	1	-	1	1	-
Spisula solidissima	-	V	-	-	V
Polinices immaculatus	-	D	-	-	-
Tellina agilis	-	-	V	V	V
Nucula proxima	-	-	V	-	-
Corbula contracta	-	-	V	-	-
Transenella stimpsoni	-	-	V	-	-
Cerastoderma pinnulatum	-	-	1	-	D
Nassarius trivittatus	-	-	V	-	-
Crustacea					
Unciola inermis	1	-	2	-	-
Unciola irrorata	2	-	4	1	2
Siphonoecetes smithianus	-	1	-	-	-
Leptochelia sp.	-	1	-	-	-

*D - Dead gastropoed or dead valves joined together
V - Separate valve
P - Present

Table 28. (Continued)

Species	Sample 16	17	18	19	20
Crustacea (cont.)					
Cirolana concharum	-	1	-	-	-
Cirolana polita	-	-	1	-	1
Ampelisca nadorum	-	-	-	-	1
Others					
Nemertean sp. #1	-	19	-	-	-
Eudendrium dispar	-	-	-	-	P

Table 29. OCCURRENCE OF BENTHIC INVERTEBRATES AT STATION 13

	Sample				
Species	22	23	24	25	26
Polychaeta					
Axiothella mucosa	1	3	-	-	-
Lumbrinereis brevipes	1	-	-	-	-
Exogone verugera	1	-	-	-	-
Marphysa belli	1	-	-	-	-
Progoniada regularis	1	1	6	3	-
Sabella microphthalma	1	-	-	-	-
Glycera dibrachiata	-	1	-	-	-
Aricidea suecica	-	1	2	-	-
Lumbrinereis paradoxa	-	-	6	3	3
Aricidea wassi	-	-	-	1	-
Phyllodoce maculatus	-	-	-	1	-
Eunice pennata	-	-	-	1	-
Unknown sp. #1	-	-	-	-	7
Mollusca*					
Astarte castanea	V	-	V	V	-
Venericardia borealis	V	V	V	V	V
Ensis directus	v	-	V	-	-
Crenella glandula	V	-	-	-	-
Placopecten magellanicus	V	-	V	V	-
Cerastoderma pinnulatum	V	-	D	V	V
Natica sp.	1	-	-	-	-
Busycon canaliculatum	D	-	-	-	-
Colus pygmaea	-	1	-	-	D
Arctica islandica	-	V	1	-	-
Margarites groenlandicus	-	1	-	-	D
Trachycardium muricatum	-	-	V	-	-

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*D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 29. (Continued)

	Sample				
Species	22	23	24	25	26
Crustacea					
Unicola irrorata	3	1	1	-	1
Ampelisca sp.	2	-	-	-	-
Byblis serrata	-	4	-	1	3
Unciola inermis	-	1	-	-	1
Eudorella sp.	-	1	-	-	-
Ampelisca declivitatus	-	-	-	4	3
Tricophoxus epistomus	-	-	-	-	4
Others					
Ophiuroidea sp.	1	-	1	-	-
Echinarachnius parma	2	-	-	-	2
Microporella ciliata	p	-	P	-	-
Sertularia argentea	P	P	-	-	-
Eudendrium dispar	P	P	-	-	-
Callopora sp.	-	P	P	-	-
Asterias vulgaris	-	-	-	1	-
Arbacia punctulata	-	-	-	1	-
Alcyonidium polyoum	-	-	-	P	-
Parasmittinia sp.	-	-	-	P	-

Table 30. OCCURRENCE OF BENTHIC INVERTEBRATES AT STATION 14

Species	Sample				
	28	29	20	21	32
Polchaeta					
Axiothella mucosa	2	-	-	3	-
Goniadidar sp.	4	-	-	-	-
Progoniada regularis	1	-	1	1	-
Eteone trilineata	1	5	-	-	-
Sabellidae sp.	1	-	-	-	-
Eteone longa	1	-	-	5	3
Aricidea suecica	-	1	-	-	-
Aricidea jeffreysi	-	-	-	-	-
Eteone lactea	-	-	1	-	-
Euchone sp.	-	-	2	-	-
Nephtyidae sp.	-	-	-	1	-
Clymenella torquata	-	-	-	1	1
Eteone flava	-	-	-	-	1
Ampharetidae sp.	-	-	-	-	2
Mollusca*					
Ensis directus	V	D	1	D	-
Cerastoderma pinnulatum	1	V	-	-	-
Astarte castanea	V	-	-	-	-
Placopecten magellanicus	-	V	-	-	V
Astarte undata	-	-	V	V	-
Venericardia borealis	-	-	V	-	-
Arctica islandica	-	-	V	V	V
Trachycardium muricatum	-	-	V	-	-
Polinices immaculatus	-	-	-	2	-
Spisula solidissima	-	-	-	-	V

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*D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 30. (Continued)

Species	Sample 28	29	30	31	32
Crustacea					
Tricophoxus epistomus	6	5	2	6	1
Siphonoecetes smithianus	-	1	-	-	-
Ampelisca declivitatus	-	1	-	-	-
Unciola irrorata	-	-	-	1	-
Byblis serrata	-	-	-	1	-
Phoxocephalus hoholli	-	-	-	1	-
Protohaustorius wigleyi	-	-	-	-	1
Others					
Callopora sp.	P	-	-	-	-
Echinarachnius parma	-	5	-	1	2
Ophiuroidea sp.	-	-	-	-	1

Table 31. OCCURRENCE OF BENTHIC INVERTEBRATES AT STATION 17

	Sample				
Species	33	34	35	36	37
Polychaeta					
Axiothella mucosa	4	2	1	6	-
Lumbrinereis acuta	4	-	-	-	-
Chaetozone sp.	1	-	-	-	-
Aricidea suecica	-	1	1	-	-
Cirratulidae sp.	-	1	-	-	-
Nephtys picta	-	-	1	-	-
Aricidea wassi	-	-	2	-	-
Nephtys bucera	-	-	1	-	-
Sigalion arenicola	-	-	-	1	-
Spiophanes bombyx	-	-	-	1	-
Scolecolepides viridis	-	-	-	-	2
Mollusca *					
Spisula solidissima	V	V	V	1	V
Tellina agilis	V	V	V	V	V
Venericardis borealis	V	-	-	V	-
Crenella glandula	V	V	V	D	V
Astarte castanea	V	V	-	V	-
Cerastoderma pinnulatum	D	-	V	V	V
Busycon canaliculatum	D	-	-	-	-
Crepidula plana	D	D	D	-	D
Nassarius trivittatus	D	D	-	-	-
Anomia simplex	V	V	-	V	V
Pandora trilineata	V	-	1	-	-
Astarte undata	-	-	V	-	-
Caecum cooperi	-	-	D	-	-
Anadara transversa	-	-	V	-	-
Abra lioica	-	-	V	-	-
Corbula contracta	-	-	-	V	-

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*D - Dead gastropod or dead valves joined together
V - Separate valve
P - Present

Table 31. (Continued)

	Sample				
Species	33	34	35	36	37
Mollusca (cont.)					
Ensis directus	-	-	-	D	-
Natica pusilla	-	-	-	D	-
Pandora gouldiana	-	-	-	V	-
Marginellidae sp.	-	-	-	V	-
Placopecten magellanicus	-	-	-	-	V
Margarites groenlandicus	-	-	-	-	V
Crustacea					
Trichophoxus epistomus	1	6	2	2	1
Cirolana polita	1	-	-	-	1
Protohaustorius wigleyi	-	2	1	1	2
Cirolana impressa	-	-	1	1	-
Ampelisca declivitatus	-	-	-	-	1
Byblis serrata	-	-	-	-	1
Others					
Echinarachnius parma	1	2	3	4	3
Nemeltean sp.#2	-	-	-	1	-

Table 32. SIZE DISTRIBUTION OF EPIBENTHIC FAUNA
(Sample QK7354-0201)

Henricia sanguinolaria	
5.0 cm	
2.4 cm	$\bar{x} = 3.6$ cm
3.6 cm	
3.2 cm	S = 1.1 cm

Asterias vulgaris	
3.6 cm	
2.9 cm	$\bar{x} = 2.7$ cm
3.0 cm	
2.3 cm	S = 0.6 cm
3.0 cm	
1.8 cm	Leg missing
2.2 cm	

Asterias tanneri	
3.6 cm	Leg missing
3.8 cm	
3.0 cm	$\bar{x} = 3.7$ cm
3.6 cm	
3.5 cm	S = 0.6 cm
4.7 cm	

Leptasterias tenera	
3.2 cm	
2.9 cm	
2.4 cm	$\bar{x} = 2.8$ cm
2.2 cm	S = 0.5 cm
2.5 cm	Leg missing
2.7 cm	Leg missing
2.5 cm	
3.1 cm	
2.9 cm	
2.1 cm	
2.6 cm	
2.6 cm	
4.0 cm	Leg missing
3.0 cm	

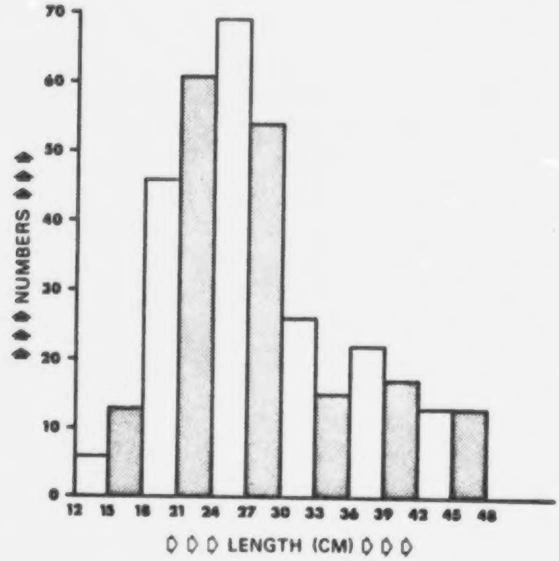

Figure 25 — Size frequency distribution of Echinarachnius parma (sand dollar) collected in a 16-ft otter trawl at Station 2. Numbers of organisms are in relation to their length in centimeters (see Figure 27).

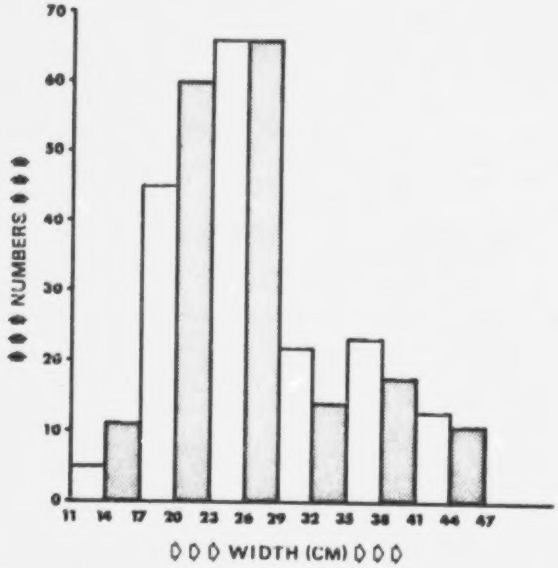

Figure 26 — Size frequency distribution of Echinarachnius parma. Size is width of organism in centimeters. Organisms were captured at Station 2 (see Figure 27).

Table 33. MACROINVERTEBRATES FROM ANCHOR DREDGE SAMPLES

	Station									
Species	1	2	5	6	8	9	11	13	14	17
Echinodermata										
Echinarachnius parma	17	19	6	15	11	30	--	4	11	3
Asterias sp.	--	4	--	1	--	--	--	--	--	1
Crustacea										
Paguras sp.	1	--	--	--	--	--	--	--	--	1
Mollusca										
Arctica sp.	--	2	--	1	1	--	--	2	2	2
Placopecten sp.	--	1	--	--	--	--	--	1	--	--
Nassaruis sp.	--	--	--	1	1	2	--	4	--	--
Polychaeta										
Nephtys sp.	--	--	--	--	1	--	--	--	2?	1
Aphrodita sp.	--	--	--	--	--	--	1	--	--	--
Unidentified sp.	--	--	1	--	--	--	--	--	2	--

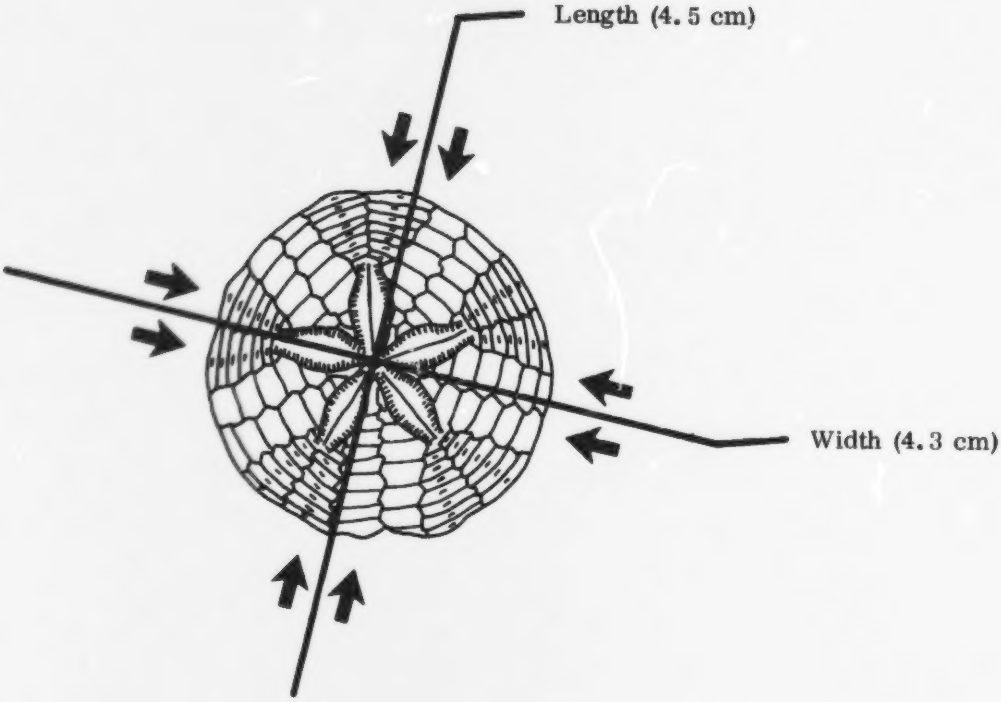

Figure 27 — Diagram of Echinarachnius parma showing length and width measurements of an individual. Length is the longest line of the sand dollar while width is the distance across the organism at 90° angle from length line.

3. Interpretation

A cursory examination of the fauna reveals approximately 120 species representing eight phyla. The annelids (polychaetes) comprise approximately 33%, the molluscs (pelecypods and gastropods) 33%, and the arthropods (crustaceans) 26%. The remaining five phyla comprise 8% of the fauna. Among the principal taxonomic groups the polychaetes were the most abundant, followed by the crustaceans and then the molluscs. Many of the molluscs were not alive when they were collected.

Among the polychaetes, *Progoniada regularis*, *Lumbrineris paradoxa*, and *Axiothella mucosa* were the most abundant species. Another lumbrinerid, *Lumbrineris acuta* and species of Paronidae (*Aricidea* spp.) were occasionally dominant in abundance. Based on mouth parts and general habits of the families, *P. regularis* and *L. paradoxa* are probably primarily carnivores, reverting secondarily to detritus feeders in the absence of suitable prey.

Among the crustaceans, amphipods (*Trichophoxus epistomus*, *Protohaustorius wigleyi*, *Unciola* spp.) and isopods (*Cirolana* spp.) were the most abundant. *Trichophoxus epistomus* was also found to be a characteristic sand bottom dweller near the mouth of the bay (Maurer et al., 1973).

As noted earlier, few live molluscs were collected. Valves of *Venericardia borealis*, *Spisula solidissima*, *Colus pygmaea*, *Cerastoderma pinnulatum*, and *Tellina agilis* were most common.

Among the remaining phyla, there were six species of ectoprocts and three species of echinoderms. Although quantitative data were unavailable for the echinoderms, the sea stars and sand dollars must be considered among the most conspicuous and characteristic species collected.

In summary, the benthic organisms are characteristic of a firm sand-shell-gravel community. The community is dominated by sea stars, sand dollars, and polychaetes. In terms of feeding types, it appears that suspension feeders and carnivores are extremely well represented. Deposit feeders and detritus feeders are poorly represented. Based on a preliminary examination, this sand bottom community is surprisingly diverse and abundant. Moreover, it is anticipated that greater attention to qualitative dredge hauls would have produced additional epifaunal species. For purposes of future monitoring, significant changes in populations of sand dollars, principal polychaetes, and some of the more fleshy ectoprocts would be indicative of changes in water quality. Based on the benthos, this site appears unpolluted.

E. HEAVY METALS IN ORGANISMS

1. Previous Work

The propensity for marine organisms to selectively accumulate certain chemical species has long been recognized (Merlini, 1971) and this natural activity must be carefully observed with current ocean dumping practices. Relatively few data exist on detrimental levels of metals in the various organisms in the marine food chains, and accelerated introduction of these materials may affect the relatively stable but sensitive metabolism of this biota.

Buelow (1968) examined metals contents from clam meats (Spisula solidissima) at an ocean dumpsite near the mouth of Delaware Bay, and found them to contain higher than expected concentrations of chromium and nickel. This organism was not collected on this cruise, although shells were present.

Davey (1972) analyzed sea clams from the same site and found similar levels as Buelow.

2. Present Cruise

Results of metals analyses for various organisms on the present cruise are shown in Table 34. Levels of all metals in the biota seem to be generally comparable with levels found in clam meats nearby except one zooplankton tow (cf. Section A, Zooplankton) that had a materially greater level than either the replicate tow at Station 9 or a tow at Station 14. This probably represents the inherent variation to be expected from the biological systems. The nudibranch from Station 2 was high in zinc and nickel. The gonad material from the sea robin, Prionotus carolinus (Linnaeus), was high in zinc also.

Copper, zinc, iron, lead, nickel, and cadmium analyses were done on 24 samples of sand dollars, Echinarachnius parma, collected from nine stations located within the existing dumpsite, an immediately adjacent area, and areas distant from the site (Table 35). Sample results were grouped on that basis.

Table 34. METALS IN MARINE BIOTA

Sample	Station	Organisms		Length	Hg mg/gWW	Pb mg/gWW	Zn mg/gWW	Cr mg/gWW	Cu mg/gWW	Cd mg/gWW	Ni mg/gWW	Mn mg/gWW	Fe mg/gWW
QK7351- 0201-1	2	Starfish (Asteroidea)	4 organisms		.0003	<.0010	.0534	.0051	.0265	.0001	<.0010	.0024	.0432
0202-1	2	Sea Robin		23 cm									
2		(Prionotus carolinus)	Brain		NSQ*	NSQ	NSQ	NSQ	NSQ	NSQ	NSQ	NSQ	NSQ
3,4			Liver & Guts		.0030	<.0010	.0182	.0002	.0040	.0004	<.0010	<.0010	.0818
5			Gonads		<.0001	<.0010	.0636	.0030	<.0010	.0003	<.0010	<.0010	<.0010
6			Muscle		.0010	<.0010	.0043	.0080	<.0010	.0007	<.0010	<.0010	<.0010
0203-1	2	Ocean Pout		33 cm									
		(Macrozoarces americanus)	Brain		NSQ	NSQ	NSQ	NSQ	NSQ	NSQ	NSQ	NSQ	NSQ
			Liver		.0003	<.0010	.0233	.0028	<.0010	.0003	<.0010	<.0010	.0768
			Gut		.0003	<.0010	.0159	.0042	<.0010	.0004	<.0010	<.0010	.0130
			Gonads		.0004	<.0010	.0209	.0029	<.0010	.0003	<.0010	<.0010	.0174
			Muscle		.0002	<.0010	.0070	.0011	<.0010	.0007	<.0010	<.0010	<.0010
0204-1	2	Ocean Pout (Macrozoarces americanus)	Whole organism	14.5 cm	.0002	<.0010	.0273	.0021	.0037	.0005	<.0010	.0021	.9689
0205-1	2	Sea Slugs (Nudibranchia)			.0001	<.0010	.0546	.0047	.0059	.0010	.0455	.0782	.2098
0206-1	2	Sand Dollars (Echinarachnius parma)	4 organisms	av. 3 cm	.0001	.0054	.0057	.0010	.0333	.0010	.0035	.0028	.0278
0202	2	Zooplankton			.0001	<.0010	.0392	.0034	<.0010	.0004	<.0010	<.0010	<.0010
0904	9	Zooplankton			.0001	.1824	.1174	.0350	.0081	.0003	<.0010	.0055	.8079
1402	14	Zooplankton			<.0001	<.0010	.0610	.0058	<.0010	.0028	<.0010	<.0010	.0264

*NSQ - Not sufficient quantity

Table 35. HEAVY METAL ANALYSES OF SAND DOLLARS, *Enchinarachnius parma*

Station	Latitude	Longitude	Code	µg/g						
				Dry Wt	Cd	Cu	Zn	Pb	Ni	Fe
1	38° 23.8'N	74° 15.3'W	QK73420101	.9786	0	2.3	6	10	0	130
1	"	"	QK73420102	1.3153	0	0.4	8.0	10	0	44
1	"	"	QK73420103	1.8224	0	0.4	5.8	8	0	60
2	38° 22.3'N	74° 14.2'W	QK73420201	.4855	0	2.1	10.8	21	0	420
2	"	"	QK73420202	.7730	0	1.6	11.3	10	0	580
2	"	"	QK73420203	1.4818	0	1.2	30	12	0	260
5	38° 18.7'N	74° 19.4'W	QK73420502	3.2121	0	1.0	4.7	5	0	134
6	38° 21.3'N	74° 16.5'W	QK73420602	.4537	0	2.8	9.9	22	0	560
6	"	"	QK73420603	.5960	0	2.1	10	17	0	360
8	38° 20.7'N	74° 19.0'W	QK73420801	.6098	0	2.0	7.0	8.2	0	250
8	"	"	QK73420802	.5215	0	4.8	6.2	19	0	280
8	"	"	QK73420803	.9327	0	1.9	5.6	8	0	310
9	38° 11.9'N	74° 32.9'W	QK73420901	2.1527	0	11.4	13.6	3.5	0	184
9	"	"	QK73420902	1.8443	0	1.0	7.0	6.8	0	330
9	"	"	QK73420903	1.6039	0	1.0	6.4	4.7	0	330
13	38° 23.4'N	74° 09.6'W	QK73421301	1.3762	0	1.1	7.3	1.8	0	240
13	"	"	QK73421303	1.0895	0	3.0	14.0	6.9	0	380
14	38° 27.8'N	73° 57.0'W	QK73421401	2.2220	.3	1.2	7.4	3.4	0	90
14	"	"	QK73421402	2.5713	.4	.8	7.7	5.8	0	80
14	"	"	QK73421403	2.0170	0	1.0	8.4	6.2	0	70
17	38° 12.1'N	74° 28.3'W	QK73421701	3.4574	.3	.7	5.9	4.3	0	120
17	"	"	QK73421702	2.1545	.3	1.4	9.3	5.8	0	120
17	"	"	QK73421703	2.3845	.2	.9	7.0	7.3	0	220
2	38° 22.3'N	74° 14.2'W	QK73540202	1.6500	1.8	8.3	254	12	0	100

Group I (Stations 1, 6, 8, 2)	Dumpsite 12 samples from 4 stations
Group II (Stations 5 and 13)	Adjacent Areas 3 samples from 2 stations
Group III (Stations 9, 14, and 17)	Distant Areas 9 samples from 3 stations

A data summary is given in Table 36. The levels of Cu in Groups I and II appear to be higher than those levels found in Group III. This suggests a trend for the concentration of Cu by those sand dollars found in the dumpsite proper and the adjacent area. The significance of this trend can only be verified through an expansion of the data base realized through more field collections and metal analyses. We feel that there is enough evidence of Cu enhancement in sand dollars under the influence of the dumpsite to warrant further investigation.

Levels of Zn do not reflect any trend or differences between those animals analyzed between the various groups.

Levels of Fe appear to reflect a slight trend for enhancement in those sand dollars collected under the influence of the dumpsite. Our recommendation is the same as that made for Cu — more data to verify the apparent trend.

3. Interpretation

These data indicate selective uptake discussed above, as well as inherent variation.

The effect of the nearby acid dumpsite may also have bearing on the occasionally high levels of materials, but the data to date are too scarce to draw sound conclusions.

The variability of the data would indicate that sustained, statistically designed sampling efforts are required, especially in the more mobile nektonic organisms and because of the nearby acid waste dumpsite.

Table 36. DATA SUMMARY OF HEAVY METAL ANALYSIS

Group I	Range: 0.4 to 4.8 Mean: 2
Group II	Range: 1.1 to 3.0 Mean: 1.7
Group III (An extraordinarily high Cu value has been eliminated: 11.4, Station 9, replicate 1)	Range: 0.8 to 1.4 Mean: 1

Zn (ppm)

Group I	Range: 5.6 to 30 Mean: 10
Group II	Range: 4.7 to 14 Mean: 8.7
Group III	Range: 5.9 to 13.6 Mean: 8

Fe (ppm)

Group I	Range: 44 to 580 Mean: 296
Group II	Range: 134 to 240 Mean: 251
Group III	Range: 70 to 330 Mean: 171

Cd, Pb, Ni

For the few instances in which some Cd, Pb, and Ni was detected in some samples, the values obtained were so close to the limit of detection that no firm conclusions could be drawn from them. In all cases, these metals were functionally below the reliable level of detection.

F. BACTERIOLOGY

1. Previous Work

Bacteriological analysis of the water column in the vicinity of this cruise was reported by the U.S. Public Health Service (Buelow, 1968). Thirty-two stations were occupied in and out of the Delaware Bay offshore sewage sludge disposal site 12 miles east of the mouth of Delaware Bay. Only two of 85 water samples at a 2-mile distance from the center of dumpsite showed any positive coliform MPN's. No sediments were collected for bacteriological analysis.

2. Survey Cruise

Ten stations were occupied in the area of the proposed interim dumpsite. Stations 14 and 17 were control areas outside the site while the remainder of stations were located in the immediate dumpsite. Water and sediment samples were collected at each station, with the exception of Station 6 where there was no sediment sample.

Water samples were taken 5 ft above the bottom using a sterile Zobell J-Z bulb sampler (Rodina, 1972). The sample was immediately transferred into a sterile French square to facilitate handling for analysis.

Sediments were subsampled from an undisturbed Shipek bottom grab using a flame-sterilized 2.7 ml cylindrical spoon. Samples were placed in a sterile French square and brought up to a 100 ml volume with sterile distilled water. This was treated as a normal bacteriological sample.

Both water and sediment samples were subjected to the standard total coliform and fecal coliform MPN (most probable number/100 ml sample) analysis as outlined in "Standard Methods for the Examination of Water and Wastewater," 13th edition, APHA, 1971.

A 3-tube, 4-dilution scheme was followed using sample portions of 10, 1.0, 0.1, and 0.01 ml.

Water sampled from a sterile dilution blank was used as a laboratory control.

Results as MPN's of coliforms and fecal coliforms are shown in Table 37. A negative result indicates an MPN index of <3 coliforms/100 ml sample at the 95% confidence limit. Positive coliform counts were recorded only for water samples from Stations 6 and 9. Fecal coliforms were not detected for any station sampled. The controls were negative for both coliforms and fecal coliforms.

3. Interpretation

The data indicate an aqueous marine environment relatively free of terrestrial bacteriological influence. The incidence of coliforms in the marine environment is generally negligible due to the reported bactericidal activity of seawater (Orlob, 1956). The two positive samples encountered on this cruise may have been due to contamination in the laboratory aboard ship. Alternatively, wastes from ocean-going commercial vessels could account for sporadic offshore contamination.

No positive coliform or fecal coliform counts were recorded for sediments sampled. This indicates a clean bottom substrate free from terrestrial contamination.

Table 37. COLIFORM, FECAL COLIFORM IN WATER COLUMN AND SEDIMENTS (MPN/100 ml)

Sample	Station	Date	Time	Depth, ft	Sample	Coliform	Fecal Coliform
QK7310-0102	1	5-1-73	1644	156	control	—	—
QK7310-0101	1	5-1-73	1644	156	water	—	—
					sediment	—	—
QK7310-0201	2	5-2-73	0735	177	water	—	—
					sediment	—	—
QK7310-0601	6	5-3-73	1725	173	water	7	—
No sample	6				sediment	—	—
QK7310-0801	8	5-3-73	1415	138	water	—	—
					sediment	—	—
QK7310-0901	9	5-4-73	0910	120	water	4	—
					sediment	—	—
QK7310-1101	11	5-2-73	1330	170	water	—	—
					sediment	—	—
QK7310-1301	13	5-2-73	1630	175	water	—	—
					sediment	—	—
QK7310-1401	14	5-2-73	1940	176	water	—	—
					sediment	—	—
QK7310-1701	17	5-3-73	1725	125	water	—	—
					sediment	—	—
QK7310-0501	5	5-3-73	1125	151	water	—	—
					sediment	—	—

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Appendix A

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Bob Swift, Scientific Coordinator
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Bill Flohr, Mate
Gordon Edwards, Cook

Appendix B

SHIP'S LOG

DATE: 5/1/73

Time	Depth	POSITION		COMMENTS Sheet 1
		3 H4	3 H5	
13:30				Check of DB Whistle Buoy >1/4 mile error - right on
14:15		3322	3107	Loran check off DA Whistle Buoy 3/8 mile off
15:00		3304	3080	Delaware Buoy Loran check >1/4 mile right on
15:24	120	3324	3067	C=100° S=10.5
15:55		3358	3046	C=100° S=10.5
16:20		3383	3030	Correction to 145 C=145 S=10.5
16:30	128	3384	3024	C=165 S=10.5
16:38		3375	3021	C=165 S=10.5
16:44	156	3370	3016	Bacti's Bottom grab Shipek
16:50	155	3365	3014	Back down for Sta. 1
18:15	155	3370	3019	Sled dredge
19:11	155	3367	3012	Sled dredge
19:25	156	3372	3011	Bottom grab Shipek
19:35	156	3371	3013	1 mi. off Sta. 1 heading 270 back
19:48	156	3365	3014	Bottom grab Shipek (2)
20:07		3366	3016	Bottom grab Shipek (1)
20:15		3368	3016	Back to Sta. 1
20:30	155	3365	3014	Set sed. trap Sta. 1 Shipek (2)
20:49	155	3367	3015	Shipek

DATE: 5/1/73

Sheet 2

Time	Depth	POSITION		COMMENTS
		3 H4	3 H5	
20:55	156	3367	3014	TV
21:00	154	3318	3018	TV camera over
21:20		3371	3016	TV camera reaches bottom
21:40		3370	3016	
21:50		3372	3015	TV up
22:08		3371	3011	Trawl set C=180 S=2k
22:28		3365	3008	Trawl up - no specimen
22:40		3365	3008	Plankton tow C=120 S=2k
23:00		3372	3004	Plankton tow up C=325 S=10.5
23:30		3371	3014	Check C=330 S=10.5

DATE: 5/2/73

Sheet 13

Time	Depth	POSITION		COMMENTS
		3 H4	3 H5	
07:10	177	3356	3009	Bacti 5 Shipek grabs Sta. 2
07:45	178	3360	3010	C=1
08:00	180	3357	3008	Anchored Sta. 2
08:10	178	3357	3008	Anchor set Anchor dredge
08:25	178	3357	3008	Sed. trap put in Anchor up, anchor dredge (2)
08:54		3360	3008	3 Van Dorn bottles Anchor dredge
09:07	177	3357	3008	Anchor dredge
09:30				Back to Sta. 2 C=8 D=218
10:00				Anchor dredge set - drift
10:22	170	3360	3008	Trawl set Anchor dredge in
11:20		3350	3017	Trawl in
11:22		3350	3017	Plankton cast
12:02	176	3357	3008	Arr. Sta. 2
12:50		3357	3003	Anchor for TV lifted
13:05	174	3363	3003	TV up head for 11 C=045 S=8
13:13	170	3370	3002	Bacti, Shipek Station 11 anchor
13:40		3370	3002	Check on drift
14:10		3370	3001	Drift check
14:30		3374	3001	Sediment trap cast, anchor up
15:15		3377	3001	Anchor dredge up, head for Sta. 13

DATE: 5/2/73

Sheet 14

Time	Depth	POSITION 3 H4	 3 H5	COMMENTS
15:30	178	3391	2995	Arrive Sta. 13 anchor dredge
16:00	170	3395	2995	Anchor dredge
16:10	175	3390	2995	Shipek, Bacti Anchor Sta. 13
1620				C=065 S=10.5k Lv Sta. 13 for Sta. 17
19:10		3471	2974	
19:25	173	3500	2968	Arrive Sta. 14 Set anchor
19:35	176	3505	2967	Shipek, Bacti, Van Dorn Anchor took hold
20:15	173			TV down
20:36	173	3512	2967	TV on bottom
21:00	173	3512	2967	Anchor dredge started Anchor up Sed. trap dropped
21:40	173	3514	2967	End sed. anchor dredge
22:00	173	3518	2967	Anchor dredge start
22:35	175	3520	2961	Plankton tow out Anchor dredge in
22:50	172	3523	2958	Plankton tow in C=250 S=8 Head for dump ground
23:55		3440	2980	C=265 S=8

DATE: 5/3/73

Sheet 19

Time	Depth	POSITION		COMMENTS
		3 H4	3 H5	
07:15	125	3181	3030	Shipek, Van Dorn (anchored) Sta. 17 Bac-T TV
08:10	125	3181	3030	TV Anchor dredge L=210
09:15		3181	3032	2nd Anchor dredge C=080
09:35	125	3200	3030	
09:50	125	3180	3030	3rd anchor dredge
10:45		3254	3023	
10:56	130	3276	3023	Enroute Station 5
11:12	151	3290	3023	Shipek - Bacti - TV - Van Dorn bottles
12:10		3294	3022	Drift check
12:40		3295	3022	Anchor dredge
13:02		3305	3020	
13:20	135	3298	3018	Dropped sediment trap
13:55	138	3318	3020	Station #8
14:14	140	3319	3018	Anchored _Shipek _Bacti _ TV
15:30		3321	3018	Anchor dredge start Anchor up
15:55		3334	3019	Anchor dredge up C=215 Back to Sta. 8
16:15		3313	3019	Sed. trap in Anchor dredge
16:30		3317	3019	Anchor dredge up
16:40	151	3313	3019	Anchor dredge set
16:50		3314	3018	Anchor dredge up

DATE: 5/3/73

Sheet 20

Time	Depth	POSITION 3 H4	 3 H5	COMMENTS
17:15	173	3013	3038	Bacti
17:45	173	3013	3042	Drifting check
18:45		3014	3343	Lift anchor
19:35		3013	3333	Arrive back at Sta. 6
21:15	181	3008	3338	135°

DATE: 5/4/73

Sheet 32

		POSITION		
Time	Depth	3 H4	3 H5	COMMENTS
07:45		3373	3043	Helicopter rendezvous
09:05	120	3217	3051	Bacti -Shipek -Van Dorns - TV Sta. 9
14:40				Loran check with Del. light buoy Right on

Appendix C

SCIENTIFIC LOG

May 1, 1973

0930 - Prepare to get underway - stow all gear

0945 - Scientific party meet with ship captain
Ship Captain - Miller
Expedition Leader - Montague
Expedition Log - Muir

Berth assignments & party assignments
Lear changed station locations - 9, 4, 14 will be changed from 5 mi. to 20 mi.

1057 - Take in Brow

1121 - Away all lines - ship underway - shift colors

1320 Loran fix-1. dead on
2. 1/4 mi. east

1500 - Loran fix - Del. light buoy - 1/4 mi. northeast
Heading 108° from Del. light buoy

1640 - On Station I - 156 ft. Loran 3370 3016 - 38°23.8 74°15.3

1644 - Bacti 100101 Shipek over 1 rep. 310101 bent arm
100102 cntl. 32101

1707 - STD 800101
100 ft. DO 11.5 Temp. 7.5 Cond. 47 pH 8.9
DO conversions: calibrations air - 7.47
really - 8.95
50 ft. DO 11.3 Temp. 10.0 Cond. 47 pH 8.9
Surface DO 11.4 Temp. 11.0 Cond. 52-56 pH 9.0

1715 - Check depth 155 ft. lead line
155 ft. fathometer

1815 - Anchor dredge 3 rep.
410101-03
420101-03
430101-03

May 1, 1973

1925 - Shipek repaired continued sampling 350101-10 33-01-01

2030 - Over sediment trap #1

2049 - Finish Shipek 10 rep.

2100 - Prepare TV for drop

2105 - TV over

2120 - TV on bottom

2150 - TV up results good 17 min. video tape

2000 - Van Dorn 580101 - 20 ft. 340101
580102 - 75 ft. 340102
580103 -145 ft.

2208 - Otter trawl - No specimens

2240 - Plankton tow

2300 - Tow up 560101

Net	FM	Cal. fact.	Revs.
#202	#2806	0.15	1910
1000	2804	0.15	5870

STD 800102

Depth ft.	Temp.	O_2	Sal °/₀₀
2	10.3	11.8	33.8
5	10.3	11.3	33.8
10	10.3	11.6	33.8
15	10.2	11.7	33.8
20	10.1	11.6	33.8
30	9.8	11.4	34.4
40	9.1	11.1	33.8
50	8.5	11.4	33.9
60	6.8	11.0	34.0
70	6.6	11.0	34.1
80	6.5	10.8	34.2
90	6.6	10.8	34.0
100	6.6	11.0	34.1
110	6.5	10.9	34.1
120	6.5	11.0	34.1
130	6.5	10.9	34.0
140	6.5	10.9	34.1
145	6.5	10.9	34.0

2400 - Bathymetry sheet 3-12 of ship log

May 2, 1973

0710 - On station #2

Depth 177 ft. Loran 3356 3009 38°23.8 74°15.3

0735 - Bacti 100201

Shipek 7 rep. 350211-15 330201-02
340201 210201
320201

0750 - Anchor dredge 3 rep. - problem with catching

410101-03
420201-03
430201-03

0800 - STD O_2 correction 8.54

Depth ft.	Temp.	O_2	pH	Cond.
Surface	10.0	11.4	8.1	50
25	10.0	11.5	8.2	54
50	8.2	11.8	8.1	54
75	7.0	11.4	8.2	49
100	7.0	11.5	8.1	49
125	7.0	11.8	7.9	51

0815 - 40 gal. of H_2O collected for AFO

0854 - Sediment trap II put in water

0900 - Van Dorn cast

580204 25 ft. 340201
580205 85 ft. 340201-02
580205 145 ft.

1100 - Otter trawl 510201-06 sea robin, flounder, slugs
sand dollars, hermit crabs

1130 - Plankton net 550202 560201
570204-06

May 2, 1973

1130 - Plankton net tow 300 ft. out 18 min.

200 μ net Cal. Fact. 0.15 Rev. 4250
4000 0.15 3110

1200 - TV drop

1215 - TV died video intermittent

1220 - Surface drifters out 9802-9900

1258 - Bottom drifters out 1 mi. NW of station
18 knot wind NNE

1305 - TV repaired and re-dropped 18 min. video tape

1313 - On station #11 Anchored 38°22.6 74°12.2

170 ft. Loran 3370 3002

1318 - Shipek 6 rep. 311101, 321101-02, 341101, 351116-20

1330 - Bacti 101101

1345 - TV drop - problem with intermittent short

1430 - Anchor dredge 3 drop

411101-03
421101-03
431101-03

1425 - Sediment trap #III

1530 - Arrive & anchor - Station #13

1533 - Anchor dredge 411301-03
421301-03
431101-03

1600 - Sighted Sargassum weed

1630 - Bacti 101301

1645 - Shipek 8 rep. 311301, 321301-02, 331301-02, 341301, 351322-26

May 2, 1973

1705 - TV drop

1735 - TV finish 25 min.

1925 - Arrive & set anchor Station #14 - 176 ft.

New coordinates 38°27.7' N 73°57.3' W

1940 - Van Dorn - Bacti - Shipek 351428-32

2017 - Current meter

3 M	.35	210°
5	.38	180°
7.5	.45	190°
10	.47	232°
15	.30	210°
20	.27	150°
30	.14	110°
40	.18	292°
50	.37	225°

2025 - TV down

2036 - TV on bottom

2045 - TV up 11 min.

2100 - Anchor dredge 3 rep. sediment trap #IV

2235 - Plankton tow out

2250 - Plankton tow in

2400 - Bathymetry

May 3, 1973

0715 - On station & anchored @ 17 74°28.3 38°12.1

125 ft. Loran 3181, 3030

0725 - Bacti 101701 Van Dorn

0730 - 40 gal. H_2O AFO

0730 - Shipek - 6 rep.
311701 321701 331701-02 341701 351733-37 371733-37

0810 - Anchor dredge - 3 rep.

0745 - TV down

0810 - TV up

1112 - On station & anchored @ 5 74°19.4 38°18.7 - 151 ft.

1125 - Bacti 100501

1130 - Shipek - 6 rep. 310501, 320501, 330501-02, 350538-42

1130 - Van Dorn 580501-20 340501
580502-75 350538-42
580503-140

1150 - TV down

1120 - TV up

1240 - Anchor dredge

1320 - Dropped sediment trap V

1205 - STD

Depth	Sal ‰	Temp	Cond.
1 M	32.55	10.2	
2	32.76	10.15	
3	31.92	10.12	
5	32.52	10.05	
10	32.46	9.96	
20	33.34	7.12	
30	33.08	6.75	
37	33.02	6.83	140 ft.

May 3, 1973

1355 - On station and anchored 8   38°20.7' 74°19.0'

138 ft. Loran 3318 3020

1415 - Bacti 100801

1430 - Shipek 3 rep. 310801, 320801, 330801-02, 350843-47

1446 - Drifters (surface) 0377-0447

1445 - TV down

1510 - TV up

1530 - Anchor dredge 3 rep.

1615 - Sediment trap VI

1715 - On station & anchored 6 38°21.3' 74°16.5'

173 ft. Loran 3013 3038

1720 - Shipek - 7 tries - very little - fine sand

1725 - Bacti

1835 - Deitz 1 Laford sampler clean

1845 - TV down

1900 - TV up

1930 - Anchor dredge 3 rep.

2043 - Drifters out (bottom 161-320)

2115 - Bathymetry

May 4, 1973

0600 - On station 3 38°20.2' 74°13.4'

0630 - Captain called CG about sick member of scientific party (Ross Johnson)

0745 - Helicopter rendezvous, CG picked up Ross Johnson

0845 - Bottom & surface drifters out 38°22.5' 74°14.0'
321-480 bottom
9900-10,000 surface

0905 - On station 9 -120 ft. 74°32.9' 38°11.9' Loran 3217 3051

0906 - Dropped sediment trap VII

0910 - Bacti 100901

0910 - Shipek 7 rep. 350948-52

0915 - Van Dorn

0940 - TV over

1005 - TV up

1013 - STD 110 ft. or 33.5 m

Temp.	Sal.	CSP	Direction	Depth
10.82	31.88	.29	005°	3
10.90	32.12	.53	357	5
10.79	32.13	.42	352	7
10.74	32.00	.50	349	9
10.48	32.38	.38	245	11
8.02	32.59	.38	222	13
7.78	32.65	.52	208	15
7.24	32.52	.40	189	20
7.0	32.62	.95	238	25
6.85	32.82	.52	240	30
6.86	32.95	.46	220	32
10.47	32.12	.40	320	11
9.68	32.49	.35	260	13

May 4, 1973

1030 - Anchor dredge - 3 rep.

1200 - Plankton tow

1215 - Clam dredge down

1300 - Clam dredge up - shells only - no live clams

1440 - Loran check with Del. light buoy - right on

Appendix D

SUPPLEMENTAL CRUISE LOG, TUG "MARY ANN"

Water sampling "Piggyback" cruise to the interim sludge dumpsite, 13-14 July 1973.

Rigged portable boom and winch aboard 110 ft tug "Mary Ann."

Departed Spruce St. Terminal, Camden, New Jersey, 1600 July 13. Picked up barge "Forest" at NE plant, departed 1730.

Weather got heavy approaching dumpsite, SW 25-30 knot winds, rough. Made station (3H4, 3356; 3H5, 3023) Lat. 38°24.5 N, 74°16.5 W at 2210 on 14 July. Lear and Thomas, with assistance from crew, made profile through thermocline with induction salinometer. Multiple hydro casts with two 6-liter PVC bottles at surface, halfway to thermocline (10 meters), halfway between thermocline and bottom (35 meters) and bottom (46 meters). (See Table 38.)

Extremely rough, seas over fantail, worked with lifejackets. Took seas over bridge. Radar, depth finder and automatic pilot out.

Secured sampling 0030.

Crew reports never having seen red sediment trap buoys in dumpsite. Normal dumping pattern is from NW corner to center and return.

Table 38. WATER QUALITY PARAMETERS ON SUPPLEMENTAL CRUISE, TUG "MARY ANN" (14 July 1973)

Sample Depth	Conductivity µhmos	Salinity °/∘∘	Temp. °C	pH	TKN mg/l-N	Total Carbon mg/l	Organic Carbon mg/l	Cd mg/l	Cr mg/l	Cu mg/l	Pb mg/l	Ni mg/l	V mg/l	Be mg/l	Hg mg/l
Surface	44.9	29.9	23.1	7.5	0.18	23.4	6.1	-	-	-	-	-	-	-	-
10 ft	44.9	29.9	23.1	-	-	-	-	-	-	-	-	-	-	-	-
20 ft	44.9	29.9	23.1	-	-	-	-	-	-	-	-	-	-	-	-
30 ft*	44.9	29.9	23.1	7.6	0.20	24.0	7.3	-	-	-	-	-	-	-	-
40 ft	44.9	29.9	23.1	-	-	-	-	-	-	-	-	-	-	-	-
50 ft	44.9	29.9	23.1	-	-	-	-	-	-	-	-	-	-	-	-
60 ft	44.9	29.9	23.1	-	-	-	-	-	-	-	-	-	-	-	-
70 ft	44.8	30.3	-	-	-	-	-	-	-	-	-	-	-	-	-
80 ft	38.5	31.4	13.7	-	-	-	-	-	-	-	-	-	-	-	-
105 ft†	-	-	-	8.1	0.28	26.7	8.9	-	-	<0.02	<0.1	<0.5	<0.1	<0.2	<0.1
138 ft (bottom)‡	-	-	-	8.0	0.27	25.9	6.0	<0.02	<0.02	<0.02	<0.1	<0.5	<0.1	<0.2	<0.1

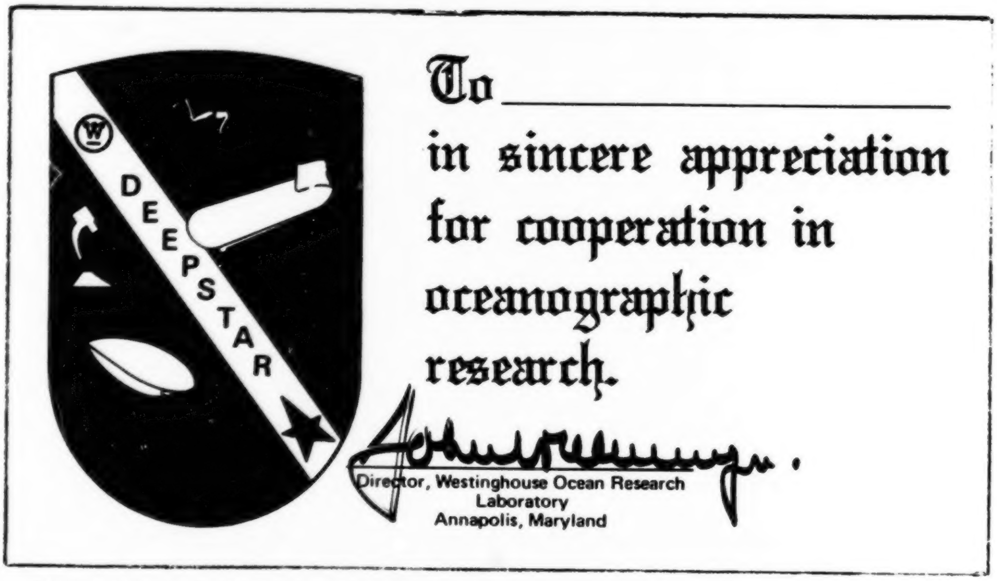
*Halfway to thermocline.

†Halfway thermocline to bottom.

‡No petroleum residues or organochlorine compounds were detected in this bottom water sample.

Appendix E

BOTTOM DRIFTER RESPONSE SHEET

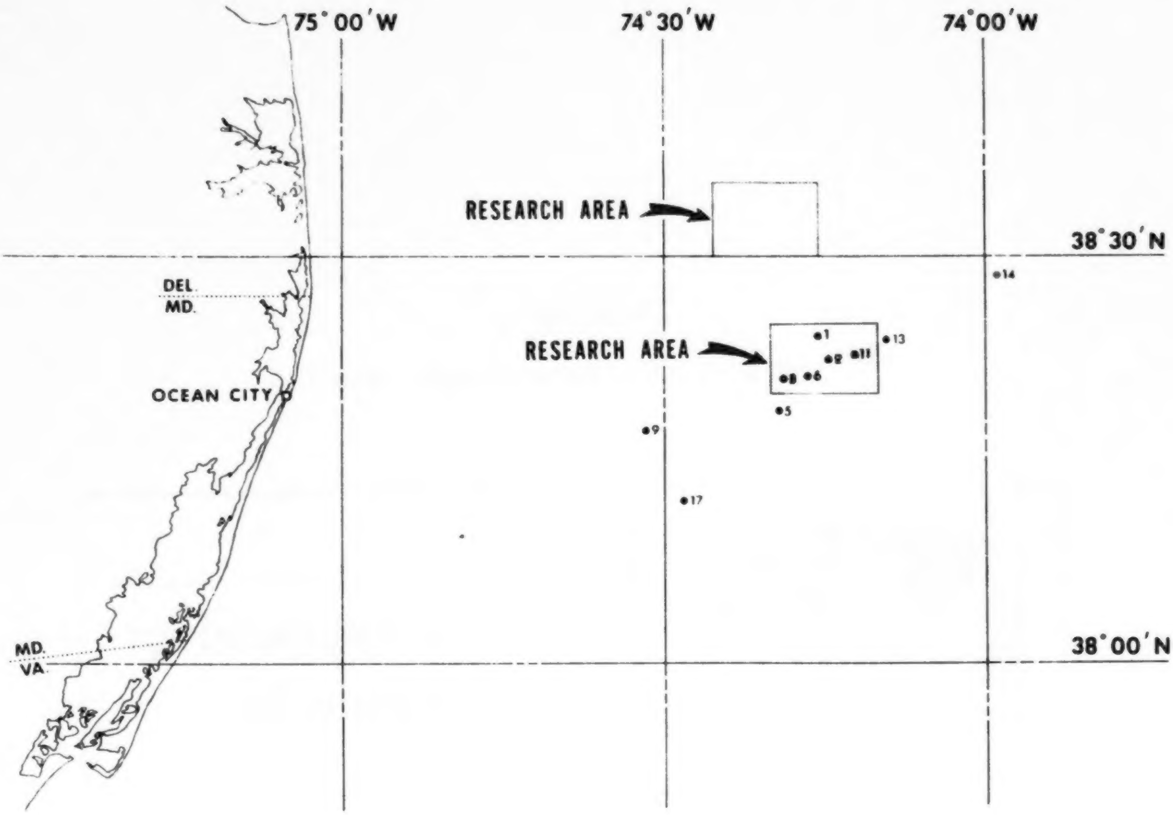


To ____________________

in sincere appreciation for cooperation in oceanographic research.

Director, Westinghouse Ocean Research
Laboratory
Annapolis, Maryland

Example of card forwarded to persons returning drifters. Reward of one silver dollar accompanied this card, with a letter of thanks and explanation of the purpose of the program.



THANK YOU!

We sincerely appreciate your returning the card from our plastic "sea-bed drifter." As you may have noticed if you found it in the water, the small weight on the stem is designed to keep the drifter barely negatively buoyant - that is, just barely floating above the bottom, but not rising to the surface. When submerged, the drifters are practically weightless, and therefore are easily moved about even by weak currents, which may be present at the sea floor.

The drifter which you found was released at __________ hours on ____________________ at the location shown above in red. We cannot tell its exact path, but the information you provided is important in understanding the overall "drift" of bottom currents in this area. From this study, we are attempting to interpret the movements of coastal waters along our valuable shorelines. Your assistance in our oceanographic research will help all of us in our efforts to understand the complex marine environments.

Harold D. Palmer

Harold D. Palmer
Manager, Aquatic Physical Sciences
Westinghouse Ocean Research Lab.